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OFFICE OF EXPERIMENT STATIONS—BULLETIN 188.

A. C. TRUE, Director.

IRRIGATION IN THE YAKIMA VALLEY, WASHINGTON.

BY

S. O. JAYNE,

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WASHINGTON:

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*Bul. 133. Report of Irrigation Investigations for 1902, under the direction of Elwood Mead, chief. Pp. 266.

Bul. 134. Storage of Water on Cache la Poudre and Big Thompson Rivers. By C. E. Tait. P. 100.

[Continued on third page of cover.]

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THE OFFICE OF EXPERIMENT STATIONS.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Office of Experiment Stations,
Washington, D. C., April 15, 1907.

Sir: I have the honor to transmit herewith a report upon irrigation in the Yakima Valley, Washington, prepared under the direction of Dr. Elwood Mead, chief of Irrigation and Drainage Investigations, by S. O. Jayne, irrigation engineer of this service.

The Yakima Valley is the largest irrigated section in the State of Washington, and the development of that valley illustrates admirably the problem which will arise in other parts of that State and in other sections of the West. This report describes the canals and the methods which have been adopted for overcoming the various obstacles which have arisen in the development of this valley. It discusses the methods of construction, of preventing seepage losses, of preparing land for irrigation, and calls attention to the necessity of providing proper drainage for irrigated lands. It also gives the cost of producing crops and the yields and returns from agricultural operations. Some discussion of the legal questions and the necessity for further legislation is given.

At present there is in the State of Washington a strong demand for legislation to encourage and aid irrigation development, and this report should prove of great value by showing the needs of the industry along this line, as well as being a valuable guide to new settlers by pointing out the best methods to be followed in reclaiming land. Its publication as a bulletin of this Office is therefore recommended.

Respectfully,

A. C. True,
Director.

Hon. James Wilson,
Secretary of Agriculture.

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IRRIGATION IN THE YAKIMA VALLEY, WASHINGTON.

INTRODUCTION.

Irrigation has been practiced in parts of the Yakima Valley, Washington, to some extent for forty years or more, but all ditches of any importance have been built within the last twenty-five years. In fact, the beginnings of the larger canal systems in operation to-day and the real awakening to the importance and possibilities of irrigation in this State date back only about fifteen or sixteen years.

For the purpose of getting information regarding conditions and practices pertaining to the irrigation work in this State, with a view to assisting those interested in possible improvement, and in the solution of various problems, work was begun by this Office in the Yakima Valley in 1900. Since then, more or less work in irrigation investigations has been done each year. Practically all of this work, with the exception of that done during the past season, has been done by Prof. O. L. Waller, special agent and expert in irrigation investigations and irrigation engineer of the State College of Washington, most of the results having been published either by this Office or as bulletins of the Washington Experiment Station.

It is the purpose of this report to review to some extent the work that has been done in past years, to present the results of more recent special studies, and to give as full information as our present knowledge will allow of the general progress so far made in the work of irrigation in the Yakima Valley.

YAKIMA VALLEY.

In the Yakima Valley are included all lands forming part of the watershed of the Yakima River and its tributaries. (Map, Pl. I.) It is situated in the south central portion of the State and extends in a general southeasterly and easterly direction from the Cascade Mountains through Kittitas, Yakima, and Benton counties, joining the valley of the Columbia River only a few miles from the southern boundary of the State. The distance from the source of the river to the junction with the Columbia is not far from 175 miles.

This valley is separated from the Columbia River watershed on the northeast by Yakima Ridge and the Rattlesnake Hills, barren and

more or less rocky, with an altitude of from 1,000 to 1,600 feet. On the south through Benton County it is shut in by the Horse Heaven Hills, while to the west it extends back from the river with a gradual rise to merge at varying distances with the foothills of the Cascade Mountains. The tributary streams come from the west, being fed by the melting snows of the mountains. They flow through minor valleys, or follow courses parallel to the numerous ridges which intercept roughly at right angles the general trend of the main valley of the Yakima. These ridges or ranges of hills close in upon the river at two points, forming, between North Yakima and Ellensburg, a narrow gorge several miles in length known as Yakima Canyon, and, a few miles below the city of North Yakima, a narrow opening through which the river flows, called Union Gap.

The portion of the valley north of Yakima Canyon, on account of its distinct separation from lower parts and its possessing characteristics peculiar to itself, might very properly be treated to some extent by itself, and in this report it is designated as the Ellensburg district.

Below Yakima Canyon the valley widens out on each side of the river, extending south to Union Gap. This area, which should also embrace the valley of the Natchez River, will be called the North Yakima district. The general conditions are not such as to make it easy to divide the lower part of the valley below Union Gap into distinct districts with prominent physical features separating them, but worthy of special mention are the lands of the Yakima Indian Reservation; those of what is generally known as the Sunnyside Valley; also farther down, the lands near Prosser, and Kiona; and the Kennewick territory, last to receive water from the Yakima River, but lying mainly in the valley of the Columbia River, which it borders.

ELLENSBURG DISTRICT.

The Ellensburg district lies wholly in Kittitas County, with the town of Ellensburg as county seat and business center. The main valley here is 15 to 20 miles wide from east to west, with agricultural lands on each side of the river. The larger body, however, is on the east side. Here the area now under irrigation is approximately 18,000 acres, and above the line of existing ditches is a further magnificent stretch of country some 60,000 acres in extent, which will some day also receive water. This portion of the valley appears in general to be quite flat, but there is in reality a good fall to the southwest, sufficient to facilitate irrigation and permit drainage. On the west side of the river there is a succession of benches, with an area of approximately 5,000 acres, irrigated from the river. There is also a considerable area of land which might be included in this district that is irrigated to some extent from small streams tributary to the river, the total acreage possibly amounting to 20,000 acres.

This district is essentially a hay, dairy, and stock country at present, the farm units being considerably larger than in lower sections of the valley. The altitude, which is about 1,600 feet, and the proximity to the mountains make the seasons somewhat shorter also, and so far scarcely any attempt has been made in the direction of diversified farming or fruit growing. It is generally conceded, however, by farmers in the district that conditions are favorable for growing apples, and recently some orchards have been started. There are at present none of commercial importance. Timothy hay is the principal crop.

NORTH YAKIMA DISTRICT.

The North Yakima district proper is about 24 miles wide east and west, and extends 7 to 10 miles north and south. North Yakima, located near the north central part, the county seat of Yakima County, is the most important town in the valley.

The river through this district runs nearly due south. On the east side is the section known as the Moxee country, with an irrigated area of approximately 12,000 acres. To the north of the Moxee, also on the east side of the river, but separated from it by the Yakima Ridge, is Selah Valley, with about 800 acres of irrigated land.

Wenas Creek from the west empties into the Yakima River near Selah station, and along this stream there are several thousand acres of irrigated land tributary to the Yakima district. Farther to the west is another tributary valley 2 to 5 miles in width, extending for about 20 miles along the Natchez River, which empties into the Yakima near the city of North Yakima. In this valley are some of the oldest irrigated farms in Yakima County, but because of the lack of transportation facilities hay has been the principal crop. A railroad is now under construction through this district, and the farms are being divided and orchards planted. There are probably 12,000 acres now irrigated in this valley.

Immediately west of the town of North Yakima is the Nob Hill section, the most highly developed portion of the Yakima Valley. Farther west and to the south are the Wide Hollow and Atanum sections. Irrigation has been practiced along the Atanum Creek for about forty years.

The soil of the North Yakima district is quite similar throughout the different sections, being mostly a sandy loam of unusual fertility. The altitude is about 1,000 feet.

This is distinctly a fruit-growing section, although hops, hay, and other crops are grown extensively. The total area now irrigated or more or less improved, lying in what we have termed the North Yakima district with its tributary minor valleys, is probably not far from 40,000 acres, while there are in course of construction works to irrigate at least 24,000 acres more.

YAKIMA INDIAN RESERVATION.

The Yakima Indian Reservation is on the west side of the river in Yakima County and includes over 100,000 acres of irrigable land which lies at only a small elevation above the river and for which water can be easily diverted. The land has been allotted to the Indians in 80-acre tracts, and they lease it to whites, who do most of the farming. The Indian Office has expended over $100,000 for canals, and there has been approximately 12,000 acres irrigated. The principal crops grown are hay, grain, potatoes, and melons.

With all the land owned by the Indians, no permanent improvements in the way of buildings, orchards, etc., are made by the parties leasing, their only object being to get everything possible out of the land while it is in their possession. Recent legislation, however, has made it possible for each Indian to sell three-fourths of his holdings in order to enable him to improve the remaining fourth. This gives the whites the chance to own their own homes, and no doubt the result will mean a rapid development in the near future.

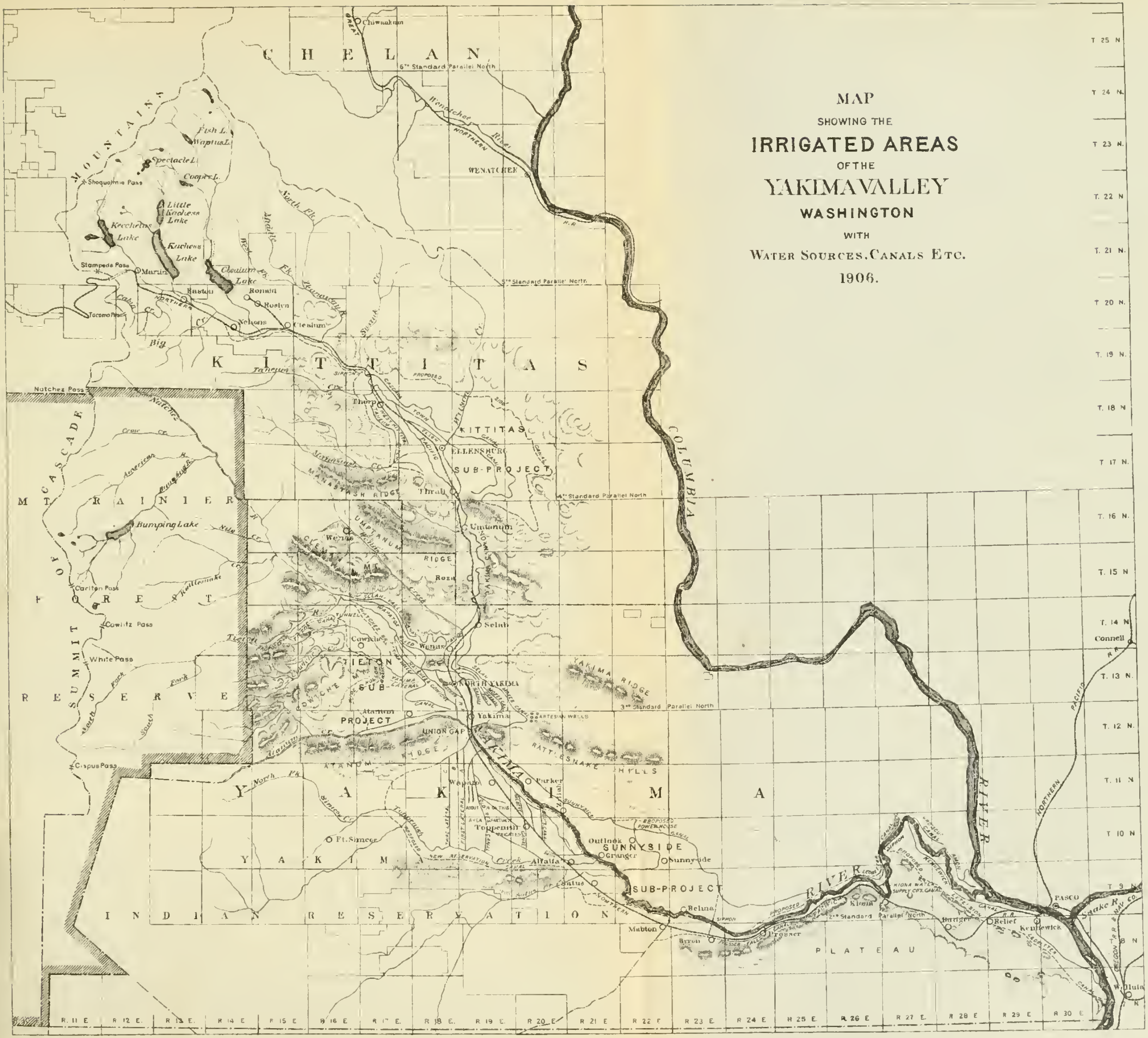
SUNNYSIDE DISTRICT.

Lying opposite the reservation and extending along the east side of the river for a distance of about 45 miles, with a width of from 1 to 8 miles, is the district supplied by the Sunnyside canal. Of this body of land, comprising 64,000 acres, something over 30,000 acres has been irrigated. There remains above the line of the present canal a magnificent body of land which, due to the expense which would be entailed to irrigate it, granting the water were available, will probably remain for many years the same arid belt that it is to-day.

The average altitude of this area is about 900 feet. The lands lying at a distance from the river are nearly all more or less undulating, while those of the lower levels nearer the rivers are more level. The uplands are better adapted to the growing of fruits, while the growing of hay crops and dairying are engaged in principally on the lower flat lands. More or less fruit is grown, however, throughout the district. Hops are another important crop extensively grown.

The soil of this district is largely a sandy loam, in most places of great depth, but in certain portions of the Sunnyside Valley the sand predominates, but appears to be equally as productive as the heavier soil.

Sunnyside, located on the Sunnyside Branch of the Northern Pacific Railroad, near the center of the district, is the principal town. The development in this district has been phenomenal during the past ten years.



IRRIGATED LANDS OF THE YAKIMA VALLEY, WASHINGTON.

PROSSER DISTRICT.

Prosser district comprises an area of some 4,000 acres under the canal of the Prosser Falls Land and Water Company, on the south side of the river in Benton County, and opposite the lands at the terminus of the Sunnyside canal. This district, perhaps, should be made to include the above-mentioned lands, as they are also tributary to the town of Prosser, which is the shipping point. The soil in this part of the valley is practically all the characteristic sandy loam, but is more or less stony and on the south side of the river is underlaid by gravel.

Farms are held in tracts of from 5 to 20 acres and fruit is coming to be the principal crop, although at present considerable hay is grown.

KIONA.

The irrigated district at Kiona is small, comprising only 300 or 400 acres. The soil is very productive and local climatic conditions are peculiarly favorable for the growing of early fruits.

KENNEWICK DISTRICT.

The lands under the Kennewick canal are the last to receive water from the Yakima River. They form a narrow strip not more than 4 miles wide at any point, extending from near the mouth of the Yakima River along down the Columbia 30 miles. The total area under the canal is about 12,000 acres, but in this district at a higher elevation there is a bordering area of from 12,000 to 20,000 acres susceptible of irrigation, which will probably sometime be watered.

Practically all the progress made in irrigation in this district has been made during the past three years, since the completion of the Kennewick canal. The low altitude (360 feet) and the sandy soil combine to make this district peculiarly well adapted to the growing of small fruit, berries, etc.

CLIMATE.

The Yakima Valley is altogether an arid district, the land in its natural condition producing nothing but sagebrush and the very scantiest supply of grass, except upon the limited areas bordering the stream, where subirrigation takes place, which permits the growth of more vegetation.

The temperature throughout the summer months is usually high, especially during July and August, but owing to the dryness of the atmosphere the heat is seldom oppressive and the nights, even in midsummer, are as a rule agreeably cool. Winters are mild, with the temperature seldom going to zero.

Comparatively strong winds during the spring are common to most sections of the valley, the prevailing direction being from the west or southwest. Occasionally also during midsummer, as a rule following a succession of unusually hot days, there will come high wind, sometimes lasting for a few hours only and again continuing for a day or more. These winds, however, seldom do any material damage, except in localities where the soil is sandy. In such places drifting sometimes injures new seeding. Usually they are followed by cooler weather.

The average annual rainfall throughout the valley is considerably less than 10 inches. With the exception of June, July, and August the precipitation is quite evenly distributed. The rainfall diminishes with the altitude, being greatest at the upper end of the valley and least in the lower part along the Columbia River at Kennewick.

The following tables are compiled from records of the Washington section of the United States Weather Bureau and are intended to show comparative climatic conditions of the different parts of the valley:

Climatic data, Yakima Valley, Washington.

Month.	Precipitation.				Temperature.			
	Ellensburg.	North Yakima.	Sunnyside.	Kennewick.	Ellensburg.	North Yakima.	Sunnyside.	Kennewick.
1905.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	°*F.*	°*F.*	°*F.*	°*F.*
January	1.81	1.19	0.87	.....	27.6	32.0	31.8	.....
February	.36	.28	.30	0.11	29.3	31.0	33.4	35.2
March	.41	.48	.48	.45	44.7	47.0	47.8	50.0
April	.16	.16	.00	.04	49.2	51.2	51.8	55.4
May	.54	.71	.75	.88	54.0	56.4	57.8	59.8
June	4.54	3.65	1.12	.....	61.3	63.2	64.3	.....
July	.15	Trace.	Trace.	.....	67.3	71.8	72.5	78.2
August	.34	.07	.13	Trace.	66.2	68.2	68.0	74.2
September	.38	.40	.52	.16	58.4	60.8	62.2	66.6
October	1.42	1.32	1.72	.78	40.0	45.2	44.8	48.0
November	.47	.25	.22	.46	36.0	36.9	.....	39.0
December	.77	.55	.37	.....	28.5	31.4	.....	33.3
Annual	11.35	9.06	6.48	2.88	46.9	49.6	.....	.....
1906.								
January	1.08	1.16	.46	.23	29.2	30.5	.....	36.0
February	1.20	.90	.99	1.00	35.2	37.7	38.2	39.9
March	1.02	1.23	.86	.37	37.6	39.8	40.6	43.2
April	.00	.00	.11	Trace.	51.5	53.7	54.6	57.8
May	1.23	1.11	.98	.93	55.7	58.2	58.4	62.2
June	.87	.69	.46	.02	57.1	60.8	61.3	66.3
July	.09	.08	Trace.	Trace.	75.2	78.9	77.0	86.4
August	.33	Trace.	Trace.	Trace.	67.4	69.9	69.8	76.0
September	.27	.24	.27	.03	59.0	62.4	60.8	64.6
October	.20	.12	.07	.51	48.5	52.4	53.0	55.4
Altitude (approximate)...feet..	1,577	1,078	764	363	.....	.....	.....	.....

From 1898 to 1905, inclusive, the mean annual precipitation was 9.47 inches at Ellensburg, 9.00 inches at North Yakima, and 6.28 inches at Sunnyside. Kennewick records are not complete covering this period, but the mean would be less than at Sunnyside.

The mean annual temperatures from 1898 to 1905, inclusive, were: At Ellensburg, 46.7; at North Yakima, 49.5; and at Sunnyside, 50.8 (excluding 1905). At Kennewick for 1898–99 the mean was 54.3. Subsequent records are incomplete.

THE WATER SUPPLY.

There is perhaps no other irrigated district in the West which is favored with a more abundant supply of water than is the Yakima Valley. The estimated discharges of the Yakima River during the irrigation season from April 1 to November 1, at Kiona, taken from the report of the United States Geological Survey for 1904, was 2,800,500 acre-feet. In the valley above, during this period there was irrigated from this same river or its various tributaries approximately 120,000 acres of land. The discharge was perhaps abnormal in 1904, but even taking the estimate for the same period for the succeeding year, which was about one-half as much, the water supply is abundant.

The Yakima River is the principal source of supply, although the Natchez River furnishes water for some of the more important ditches, and as it empties into the Yakima contributes at certain stages considerable water to that stream. Besides these rivers, the Teanneway River, Taneum, Manastash, and other creeks in the Ellensburg district, and Wenas, Cowiche, Atanum, Toppenish, and Satus creeks in the lower valley supply water for large areas at certain stages, but nearly all fall short before the end of the season.

While the water supply of the valley is generally abundant, during parts of August and September there has been in the last two or three years more or less distress from lack of water for the various canals, and trouble between rival companies has at times seemed imminent. The difficulty is that although there is plenty of water it does not come down at the right time. For instance, of the run-off in 1904, 2,714,700 acre-feet was discharged during the first four months of the irrigating season, and the discharge during the last three, when water was most needed, was only 85,800 acre-feet. The water comes from the melting snow, and if hot weather or prolonged rain in the mountains comes early in the spring there is liable to be a shortage late in the season.

There is more of the very best land still unirrigated than there is at present under cultivation in the Yakima Valley, and its development will depend mainly upon the feasibility of storing the water to be used during two or two and one-half months when the natural flow is insufficient.

There are five reservoir sites, and at two of them temporary dams are now being built. At the head of Yakima River Lakes Cle-alum, Kachess, and Keechelus have a combined capacity of about 370,000 acre-feet; Bumping Lake at the head of the Natchez River has a capacity of 22,000 acre-feet, and McAllisters Meadows at the headwaters of the Tieton River, 35,000 acre-feet. This gives a storage capacity of about 427,000 acre-feet. This would maintain a flow of 2,300 cubic feet per second for two and one-half months.

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This should be ample water for at least 150,000 acres of land and by economical use it might be made to supply a great deal more. (The above figures are taken from the report of the United States Geological Survey.) The storage capacities of these reservoirs could also be increased to nearly double the above amount, and even then they would hold only a small portion of the available water.

The following tables give the discharges of the Natchez River at its mouth, and of the Yakima River at Kiona. They show that during the early months of the summer there is a very large surplus of water, but during August very little remains after the numerous irrigation canals have been supplied. Below Kiona there are at least three canals to be supplied, so that the discharge at that point does not represent the exact discharge into the Columbia River. At the mouth of the river during parts of August and September of 1906 the channel was almost dry.

Estimated monthly discharges of Natchez River near North Yakima, Wash.

Month.	1902.		1903.		1904.		1905.	
	Mean.	Total.	Mean.	Total.	Mean.	Total.	Mean.	Total.
	Cub. ft. per sec.	*Acre-feet.*	*Cub. ft. per sec.*	*Acre-feet.*	*Cub. ft. per sec.*	*Acre-feet.*	*Cub. ft. per sec.*	*Acre-feet.*
January	1,943	119,470	2,352	144,619	1,691	104,000	577	35,480
February	1,210	67,200	1,084	60,202	1,245	71,610	537	29,820
March	1,211	74,461	1,355	83,316	1,511	92,910	1,977	121,600
April	2,638	156,972	2,623	156,079	5,706	339,500	1,371	81,580
May	5,282	324,777	5,704	350,725	5,016	308,400	1,518	93,340
June	3,782	225,045	8,459	503,345	4,074	242,400	2,276	135,400
July	1,845	113,445	2,491	153,166	2,076	127,600	882	54,232
August	589	36,216	585	35,970	436	26,810	268	16,480
September	263	15,650	296	17,613	189	11,200	184	10,950
October	390	23,919	1,673	102,869	284	17,460	730	44,890
November	820	48,793	1,972	117,342	832	49,510	432	25,710
December	975	59,950	2,244	137,978	816	50,170	350	21,520
The year	1,746	1,265,898	2,570	1,863,224	1,989	1,442,000	925	671,000

Estimated monthly discharges of Yakima River at Kiona, Wash.

Month.	1902.		1903.		1904.		1905.	
	Mean.	Total.	Mean.	Total.	Mean.	Total.	Mean.	Total.
	Cub. ft. per sec.	*Acre-feet.*	*Cub. ft. per sec.*	*Acre-feet.*	*Cub. ft. per sec.*	*Acre-feet.*	*Cub. ft. per sec.*	*Acre-feet.*
January	6,414	394,381	6,938	426,601	3,144	193,300	2,126	130,700
February	3,663	203,433	2,985	165,778	2,234	128,500	1,972	109,500
March	4,281	263,228	4,018	247,057	3,800	233,700	8,477	521,200
April	6,869	408,734	7,426	441,878	15,800	940,200	4,998	297,400
May	13,388	823,196	12,816	788,025	13,860	852,200	4,720	290,200
June	7,416	441,283	18,182	1,081,904	10,690	636,100	7,143	425,100
July	4,245	261,015	5,192	319,244	4,654	286,200	1,757	108,000
August	1,009	62,041	1,119	68,805	551	33,880	240	14,760
September	303	18,030	924	54,982	232	13,800	304	18,090
October	808	49,682	3,006	184,832	620	38,120	2,522	155,100
November	2,134	126,982	2,979	177,263	1,892	112,600	2,071	123,200
December	2,917	179,359	5,004	307,684	3,166	194,700	1,980	121,800
The year	4,454	3,231,364	5,882	4,264,053	2,054	3,663,000	3,192	2,315,000

A better measure of the total supply during the critical months of the irrigation season is given in the table on page 17, which shows the discharge at Union Gap and the diversions above that point, during July and August, 1903.

Discharge of Yakima River at Union Gap, and water used above Union Gap, 1903.

[In cubic feet per second.]

Day.	Union Gap discharge.		Water used above Union Gap.		Total.	
	July.	August.	July.	August.	July.	August.
1	6,300	2,420	850.4	896.1	7,150.4	3,316.1
2	6,000	2,420	848.4	881.9	6,848.4	3,301.9
3	6,000	2,420	846.4	878.9	6,846.0	3,298.9
4	6,000	2,100	840.5	876.3	6,840.5	2,976.3
5	6,000	2,100	864.7	887.5	6,864.7	2,987.5
6	5,700	2,100	858.7	847.1	6,558.7	2,947.1
7	5,400	1,960	848.3	852.5	6,248.3	2,812.5
8	6,000	1,960	844.8	862.6	6,844.8	2,822.6
9	6,000	1,820	855.0	964.1	6,855.0	2,784.1
10	5,700	1,820	857.1	910.2	6,557.1	2,730.2
11	5,400	1,700	859.6	919.5	6,259.6	2,619.5
12	5,090	1,700	860.0	924.7	5,950.0	2,624.7
13	4,760	1,570	864.2	920.0	5,624.0	2,490.0
14	4,500	1,570	862.8	1,021.3	5,362.8	2,591.3
15	4,220	1,450	862.5	922.2	5,082.5	2,372.2
16	4,220	1,450	862.9	922.2	5,082.9	2,372.2
17	4,220	1,340	859.0	917.9	5,079.0	2,257.9
18	3,960	1,340	856.9	918.7	4,816.9	2,258.7
19	3,960	1,240	855.9	915.6	4,815.9	2,155.6
20	3,730	1,240	856.6	915.9	4,586.6	2,155.9
21	3,730	1,240	796.4	877.7	4,526.4	2,117.7
22	3,730	1,140	795.0	925.6	4,525.0	2,065.6
23	3,520	1,140	799.7	925.8	4,319.7	2,065.8
24	3,520	1,140	851.7	924.2	4,371.7	2,064.2
25	3,520	1,140	844.6	918.2	4,364.6	2,058.2
26	3,520	1,140	846.7	916.1	4,366.7	2,056.1
27	3,260	1,040	835.3	924.4	4,095.3	1,964.4
28	3,030	1,040	833.3	858.7	3,863.3	1,898.7
29	3,030	1,040	857.7	854.0	3,887.7	1,894.0
30	3,030	1,040	795.8	847.8	3,825.8	1,887.8
31	2,600	1,040	792.3	836.7	3,392.3	1,876.7
Mean	4,505	1,542	844.0	902.0	5,352.3	2,445.9

ARTESIAN WATER.

In the eastern part of the Moxee district above all existing canals there is a considerable area of land irrigated by water from artesian wells, of which there are fifteen or twenty in use. These wells are from 600 to 1,100 feet in depth and discharge from a small fraction of a cubic foot per second to about 2 cubic feet per second. The temperature of the water varies from 67° F. to 80° F. More wells are being drilled at present, but late wells drilled at lower levels have in some instances diminished the flow of earlier ones to such an extent that now the water has to be pumped from them, and this source of water supply will probably never be of great importance in the Yakima Valley at large.

During the first years that these wells were used they were allowed to flow continuously the year around, and as a result considerable injury was done to some farms by the concentration of alkali, which was brought to the surface by overirrigation. To prevent further damage from this source a law was passed by the State legislature in 1901 which provides that except for domestic use the wells shall not be allowed to flow between October 1 and April 1.

WATER RIGHTS.

The first recorded claim to water in the Yakima Valley was dated February 21 and filed February 23, 1876. This notice describes the place of diversion and states that water is to be used for irrigation, but does not state the amount. Since that date there have been recorded some 200 claims to the use of water from the Yakima River and tributary streams. These claims are for amounts ranging from a few miner's inches to the entire flow of the stream at certain points. Almost invariably, however, the filings have been made for quantities far in excess of the appropriators' needs or ability to use. As the laws of the State prescribed no limit to the amount that might be claimed, parties filing were usually careful to make their claims large enough to cover all possible contingencies.

The first ditches were small and built by individual farmers in a very crude way for the irrigation of lands lying close to the streams, onto which water could be easily diverted. Later a number of farmers in a community would unite and build larger and better channels for the conveyance of the water to their lands, and it was under this system of cooperation that most of the old ditches of the valley were built. Later came the large irrigation companies with capital to build ditches where the early settlers had certainly not the means, and perhaps not the desire to have them. With the larger companies came larger demands for the water until claims have been filed which in the aggregate exceed many times even the flood flow of all the streams of the Yakima drainage basin.

An enactment of 1891 requires that construction of the works by which water is to be diverted shall begin within six months after the filing of notice, and as a consequence many filings made with speculative intent have lapsed. Many of the earlier small ditches as well as some more important later ones—for instance, the smaller ditches on the Yakima Indian Reservation—have no recorded claims and base their rights upon use only. The majority of ditches throughout the valley have never used anything like the full amounts of their claims, and here arises the question as to whether owners of such ditches can still lawfully claim and hold the right to use the full amounts specified in their filings. Have they by the use of a few cubic feet of water per second legally acquired the right to tie up and hold as their own for an indefinite period the entire amount filed upon? Upon the assumption that they can acquire and hold rights in this way, perpetual water rights are now being sold to investors.

As an inevitable consequence of the lax and inadequate laws governing the appropriation and use of water, the problem of water rights in the Yakima Valley is one of the most perplexing ones yet unsolved. Under present conditions no one's rights are definitely known, but so long as all got what water was needed this fact seemed

to make little difference to anybody. With the gradual development of the country, however, a shortage of water began to be apparent. This shortage was felt first along the creeks, and in most instances rights to water from them have been settled by court decrees. It has been only during the last three years that the shortage in August has caused uneasiness along the Yakima River. In 1905, however, the situation began to take on a rather serious aspect and it seemed that litigation involving all the conflicting interests was bound to ensue. In fact a suit was started, but at this stage the United States Reclamation Service, by securing an option on the Sunnyside canal, was instrumental in bringing about an agreement by which litigation was warded off for the time, and the question of rights is still unsettled. The Reclamation Service, under the State law which permitted the withdrawal of waters, secured control of the flood flow and storage sites, and no recent filings of great importance have been made by private parties or companies.

The county records, further than that they give a history of claims, are practically valueless for data as to actual rights to water, as there is nothing to show what claims have lapsed or what amounts of water are being or have been used under those that have not lapsed. Realizing the total inadequacy of existing data bearing upon this question, and also that a day of reckoning was fast approaching, this Office, in cooperation with the State experiment station of Washington, began a study of the situation in 1903 for the purpose of making up to some extent the deficiency of existing records pertaining to the use of water in the Yakima Valley. Although the work was not begun until the last of June, much valuable data were collected. The investigations included gauging all the important canals, determinations of acreage, etc., abstracting all recorded filings in Kittitas and Yakima counties, and such information regarding the value of claims as was available was secured. The results of the work, being of the greatest interest to the parties of the Yakima Valley, were published as Experiment Station Bulletin 61 of the State college of Washington.

The investigations of 1903 showed that, to supply the ditches then in use, there had been claimed 17,351 cubic feet per second. The old reservation ditches for which no claims were filed used in 1903 about 217 cubic feet per second. The ditches covered by decrees, at the rate of 1 miner's inch per acre call for 823 cubic feet per second. This makes a total of 18,391 cubic feet per second. Besides this, one of the companies now in operation has filed upon the entire flow of the Yakima River, and another one on all of the Natchez, at their respective points of diversion.

The table following shows the dates on which the filings of practically all the canals were recorded, together with approximate acreage under them, and the mean discharges through July and August, 1903.

Canals heading in Yakima River or tributaries, with areas covered, water used, and amounts claimed.

Canal.	Area cultivated.	Under ditch, not cultivated.	Mean of water used, 1903.		Amount claimed.	Date of filing.
			July.	August.		
	Acres.	*Acres.*	*Cub. ft. per sec.*	*Cub. ft. per sec.*	*Cub. ft. per sec.*	
Ellensburg district:						
Ellensburg Water Co	7,000	3,000	126.5	140.0	None.	[a]Apr. 25, 1889
Olson, or Mill ditch	1,200					
Mill near Thorpe	785				None.	
West Kittitas Irrigation Co	5,356	1,428	41.3	46.1	150	———, 1889
Bull ditch	2,200				None.	
Cascade Canal Co. (from river)		15,000			500	Feb. 28, 1903
Kline, Castle & Coble					100	
Maxey & Powell			1.0	1.0	4	
Abbott & Grandall			2.0	2.0		Aug. 26, 1889
Cascade Canal Co. (from Lake Kachess)					500	Mar. 1, 1903
Joseph Becker					16	May 6, 1893
Fogarty ditch					50	May 21, 1890
McGinnis	200				40	June 2, 1890
Reed & Ramm					8	May 27, 1890
Teanaway group	1,765	1,305				
James Masterson					10	
L. O. Seaton			20.0	20.0	90	July 25, 1884
Samuel Bates			1.3	1.3	13	Aug. 23, 1884
Giles & Castor	200		3.2	3.2	20	May 22, 1890
Thomas			4.0	4.0	10	July 21, 1900
Maeilvane ditch			1.0	1.0	6	May 24, 1890
Lower Yakima group:						
Selah-Moxee	5,500	500	51.0	55.0	150	Nov. 9, 1900
Fowler	2,750		22.0	22.0	160	
Hubbard	3,000	1,300	26.0	26.0	150	Aug. 11, 1892
Moxee			12.0	12.0		
Taylor	1,000	400	7.0	7.0	20	Mar. 24, 1888
Reservation canal	7,000	11,000	128.0	135.0	None.	
New reservation canal		24,000			1,000	Feb. 19, 1903
Gilbert ditch	2,850		55.0	54.0	None.	
Toppenish ditch	1,000		19.0	19.0	None.	
Toppenish No. 1	480		9.0	9.0	None.	
Konnewock					800	June 20, 1889
Sunnyside canal	26,016.9	38,000	640.0	685.0	1,000	Mar. 24, 1891
Prosser falls	1,502	2,000	16.2	16.0	All river.	July 18, 1893
Ledbetter	350		4.0	4.0	1,000	July 12, 1892
Northern Pacific Irrigation Co. (Kiona)	300	3,000	7.5	7.0	1,000	Aug. 28, 1889
Northern Pacific Irrigation Co. (Kennewick)	1,000	13,000	42.0	40.0	300	Aug. 6, 1891
Kiona Improvement Co	15	200	0.2	.2	None.	
Nelson Rich (Dudley app. riparian rights, G. S. Taylor, owned by Prosser Falls Co.)	300	200			200	Aug. 17, 1892
Electric light plant, Prosser					5,000	Sept. 3, 1902
Natchez Valley:						
Wapatox	1,180	1,400	30.0	37.0	30	Apr. 13, 1888
Selah Development Co	5,500		64.0	65.0	11	Nov. 13, 1888
Yakima Water, Light and Power Co					400	Jan. 3, 1902
Shanno	1,000	600	22.0	22.0		May 1, 1887
Yakima Valley Canal Co	3,500	700	51.0	64.0	150	July 27, 1894
Fruitvale	500		11.0	11.0	5	Jan. 28, 1902
Upper Scott	280	30	6.0	6.0	40	Old app.
Lower Scott	500		11.0	11.0		
La Fortune	325	76	7.0	7.0	1,000	Apr. 23, 1892
Lasswell	400		9.0	9.0	25	Mar. 19, 1886
Union	2,300	400	24.0	23.0	None.	
Broadgauge	500	300	11.0	11.0	16	———, 1885
Nile Creek	500		11.0	11.0	12.8	June 11, 1888
Do					20	Aug. 26, 1887
Do					30	Mar. 16, 1903
Natchez Canal Co	1,850		54.0	50.0	100	Apr. 1, 1889
R. S. & C	200	200	4.0	4.0		
Natchez and Cowiche Co	1,400		39.0	36.0	All river.	Feb. 9, 1895
Schuller & Rodenbaeh	260		6.0	6.0		
Sinclair & Cobb	1,500		33.0	33.0	12.5	Mar. 10, 1903
Powell	220		5.0	5.0	40	Apr. 7, 1902
Bosanger	480		11.0	11.0		
Cox	300		4.0	4.0		
City	.640		14.0	14.0	None.	
Kelly, W. S. Stevens	485	50	30.0	30.0	6	Dec. 31, 1898
Addison Cobb, Lowery	310		7.0	25.0	30	May 1, 1888
Robert McHaffy					12	Apr. 13, 1903
James A. Beck					50	May 19, 1903

[a] Began using.

DECREES.

The decree apportioning the waters of Wenas Creek allows a supply for 590 acres at the rate of 1 cubic foot per second for each 40 acres, and the surplus water, if any, is to be distributed among other settlers. Less than one-eighth of the improved lands tributary to Wenas Creek receive water after July 1.

On Nanum Creek and the other small streams where water rights are covered by decrees, the conditions are similar and only a small portion of the lands receive water through the entire season.

In the decrees the lands are usually divided into different classes designated as Class A, Class B, Class C, etc., depending upon the quantity of water allowed or upon the part of the year during which they are permitted to use it. Lands in Class A perhaps will be entitled to use water during the entire season; those in Class B, only during certain months when there is a surplus above the requirements of Class A, and those in Class C when there is more than is needed by the two foregoing classes. The details with reference to the division vary, of course, under the different decrees, but it would be very difficult in most cases to make divisions in accordance with the specifications of the decrees, and there is usually no serious attempt to do so.

The total number of acres watered from the various creeks, most of which land is covered by decrees, is possibly 30,000, while the total acreage now under irrigation in the entire valley is estimated as between 125,000 and 150,000 acres.

DISTRIBUTION AND REGULATION OF THE WATER SUPPLY.

In Kittitas County the county commissioners are empowered to appoint each year a water commissioner, whose duty it is to divide the waters of streams in accordance with the terms of decrees. He acts only when called upon to do so by the interested parties, but is paid $20 per month throughout the year.

The distribution and regulation of water under the various decrees is very unsatisfactory. There are as a rule no measuring weirs or other devices by which equitable divisions can be made. In Yakima County there is not even a water commissioner.

When the Reclamation Service became an interested party in the Yakima Valley, agreements were entered into with all the important ditch companies taking water from the Yakima and Natchez rivers, whereby the allowance of each was limited to a certain stipulated amount. These agreements were entered into voluntarily and are recorded on the books of the county auditors. They define no rights, as the terms specify only that water shall not be used in excess of a certain stipulated quantity. There is no authority to compel a compliance with these agreements, and during August, 1906, when the shortage began to be felt, the Reclamation Service sent out its men to check up the amounts being diverted by the different ditches. In

a few instances it was found that water in excess of the agreed amount was being used, but upon being notified of this fact the managers of these ditches had the gates closed sufficiently to keep within their allowances, and no friction occurred. As the various companies have no means of measuring the water diverted by their canals, they do not know how much is being taken, and are very apt to divert more than they are entitled to.

The following table gives the amounts of water to which the different ditches have agreed to be restricted, the average diversions during August, 1905, and also the names of ditches which had not entered the agreement prior to July, 1906, and the diversions made by them; and an estimate of the total amount of water necessary to meet all requirements of present ditches under conditions of the agreement. The ditches for which there is nothing, entered in the last column of the table, are those which had not entered the agreement. This statement was supplied by the office of the Reclamation Service at North Yakima, Wash.

Agreed division of water of Yakima River and diversions during August, 1905.

Name of district and ditch.	Average diversions.	Agreed amounts
KITTITAS VALLEY.	*Cub. ft. per sec.*	*Cub. ft. per sec.*
Ellensburg Water Co	125	124
The West Side Irrigation Co	66	62
Olson et al	20	23
Fogarty	7	.....
Bull Canal Co	23	.....
Total	241	209
YAKIMA VALLEY.		
Selah-Moxee Co	78	78
Taylor Ditch Co	17	23
The Moxee Co	32	38
Fowler Ditch Co	23	23
Wm. Granger	3	2
Total	153	164
NATCHEZ VALLEY.		
Selah Development Co	66	105
Clark et al	19	.....
Sinclair & Cobb	6	2
Addison Cobb	1	0.3
Wapatox Ditch Co	45	50
Foster Natchez Canal Co	1	.....
Shafer et al. (Lowery)	17	.....
Allen et al. (Kelly)	2	.....
Upper Scott (Lee et al.)	6	.....
La Fortune Ditch Co	7	.....
Lower Scott (Johncox et al.)	5	.....
Basket Fort or (Lasswell)	4	.....
Natchez Canal Co. (Gleed)	75	67.25
John Marissy (et al.)	4	3.50
Yakima Valley Canal Co	61	62.50
Schuller & Rodenbach	4	4
John Schuller (incl. in 26)	1	0
Leach & White	8	6
McCormack & Long	8	5
Chapman et al	6	5
Nelson et al	7	4.5
Natchez and Cowiche Ditch Co.	43	40
Broadgauge Ditch Co	10	9.12
Northwest Light and Water Co. (Inc)	6	0

Name of district and ditch.	Average diversions.	Agreed amounts.
NATCHEZ VALLEY—cont'd.	*Cub. ft. per sec.*	*Cub. ft. per sec.*
The New Shanno Irrigation Co	30	15
Fruitvale	10	10
R. S. & C. Irrigation Co	9	12
Old Union Ditch Co	65	65
City of North Yakima	18	2
Rodenbach	0	1.5
Total	544	469.67
BETWEEN UNION GAP AND KIONA.		
Indian reservation canals	269	.....
Sunnyside canal	626	.....
Prosser Falls Light and Power Co	8	30
Northern Pacific Irrigation Co. (Kiona)	32	23
Total	935	53
Northern Pacific Irrigation Co. (Kiona)	111	175
Grosscup (The Yakima Co.)	7	.....
Amon (Benton Water Co.)	4	.....
Total	122	175
Waste into Columbia River	100	.....
Grand total	2,095	1,070.67
Partially defined claims, estimating defined portion		15.43
Partially defined claims, estimating undefined portion		15.44
Total defined claims		1,883.10
Total undefined claims		110.44
Grand total		1,993.54
Margin to meet possible future claims		101.46
Grand total of diversions + all claims and margin		2,095.00

The present agreement relative to the distribution of water has brought about a temporary peace, but the fact that a certain ditch company agrees to take only a limited amount of water is no evidence of a right to take even that amount or any at all, and no doubt in many instances, if the truth were known, the quantities agreed upon are far in excess of the just requirements. Anyone, no matter whether he has previously used water or not, or regardless of what may have been claimed, can sign an agreement stating that in the future his diversions of water will be limited to a certain quantity, but this does not define his original right to the water, and thus this agreement does not settle anything and only guarantees to a certain extent that water in excess of these agreed amounts will be available for further irrigation work.

One of the objections to adjudication of rights made by those who are opposed to the plan is the cost that would be involved. Mr. R. P. Teele[a] gives some interesting data with reference to cost in the adjudication of rights along the Boise River and along the Upper Snake River in Idaho.

The cost of surveys, maps, and statements for the Boise River was $10,704.60 and the total area irrigated 102,505.4 acres, and the additional irrigable area under existing canals 127,421.9. This makes a cost of 10.4 cents per acre irrigated, or 4.7 cents per irrigable acre for which water is claimed.

The surveys on the Upper Snake River covered 290,679 acres of irrigated land and an additional area 502,501 acres of irrigable land, at a total cost of $28,000. This is at the rate of 3.5 cents per acre for the entire area, or 9.6 cents per acre irrigated.

The legal proceedings in the Boise River case cost $468.60. The suit was started in 1902, the trial began in April, 1905, the hearing was completed in May, 1905, and the judgment was rendered December 1 of that year. In this suit there were 135 claimants involved.

With what knowledge is already possessed, the surveys in the Yakima Valley should not cost so much as in the cases above mentioned, and the total cost per acre for complete adjudication should not exceed that of the Idaho cases.

The defining of rights and their administration are the two most crying needs in the Yakima Valley, and if these things were provided for now, it would be the means of preventing a repetition of the Yakima Valley's experience in other parts of the State where development is only now beginning to receive attention; for the use of water for irrigation and power in the State of Washington is only fairly begun.

CANALS.

To attempt a careful description of every ditch in the Yakima Valley would only add to the length of this report without materially

[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 168, p. 51.

increasing its value, and for this reason a large number of small ditches which divert but small streams will receive no special mention. Beginning first with the ditches of the Ellensburg district, at the upper end of the valley, they will be described more or less in order as they occur along down the valley.

CASCADE CANAL.

The Cascade canal is the first one of importance taking water from the Yakima River. The diversion is made from the left bank in sec. 23, T. 19 N., R. 17 E. The company filed on 1,000 cubic feet per second of water in Lake Kachess November 19, 1903, and on 500 cubic feet per second from the river February 28, 1903.

The canal is 43 miles long and is intended to supply about 15,000 acres of land lying on the east side of the river above the line of the old town ditch. Construction was done during 1904 and cost about $225,000. It was necessary to build 7 miles of flume, which was done by contract, at the rate of $19 per thousand for rough lumber in place and $21.50 for surfaced lumber. This flume is 8 feet wide inside and is intended to carry 4 feet of water. The lining as originally built was of 1½-inch fir shiplap. This, however, proved very unsatisfactory, as it warped in such a way as to open the joints, so the entire flume was lined again with 1-inch rough pine over the original lining. The flume extends along the sides of a steep gravelly hill, and the company was persuaded that it would be best to excavate a bench to set it on. This was done at large expense to the company. It was a very satisfactory arrangement for the contractor who built it, as it made it easy to get the material in place; but after the structure was completed the gravel rolling down the hill and banking up behind the flume caused no end of trouble, even tipping some of it over and pushing it down the hill. The original cost of this flume was $48,000, not including the excavation of the bench. During the first year it was necessary to expend $15,000 in repairs. Since then $7,000 to $8,000 has gone into it, and still $2,000 more should be spent to put it in good condition.

There is a tunnel 848 feet long which was excavated by contract at $7 per linear foot. The contract for earthwork was at the rate of 14½ cents per cubic yard, cement gravel 35 cents, and rock 50 cents.

The section of the canal in earth has a bottom width of 10 feet, side slopes 1½ to 1, with embankments 5 feet high and 4 feet wide on top. The grade of the first 8 miles—most of which is flume—is 2 feet in 5,000, and below this it is 1¾ feet in 5,000. It was the original intention of the company to build a rock-fill crib dam at the outlet of the lake for the purpose of storing water, but different arrangements have since been made with the Government interests.

The canal was built and is owned by a cooperative company com-

posed of farmers who own the land to be irrigated, and no stock was sold to others than landowners and only stock owners are allowed the use of water. Money for the construction was raised by a bond issue, on which there is still outstanding a debt of about $90,000. About 8,500 acres of land is now under cultivation, most of which is valued at about $80 per acre. Land in this same district, however, but with older improvements under the Town ditch, is valued at $100 per acre. This is seeded to grass.

It is estimated that the ultimate maintenance fee will be not more than 80 cents per acre per annum.

WEST KITTITAS CANAL.

The West Kittitas canal, owned by the West Side Irrigation Company, a cooperative association, heads in the Yakima River on the right bank in sec. 23, T. 19 N., R. 17 E., about 3 miles above Thorpe. It is about 15 miles in length and supplies water for 5,000 or 6,000 acres of land. Construction of this canal was commenced in 1889, and its cost is estimated at approximately $50,000.

This company was incorporated with a capital stock of $30,000, which was divided into 600 shares of $50 each. The annual maintenance fee is about $3 per share, or about 35 cents per acre.

TOWN CANAL.

The Town canal is controlled by the Ellensburg Water Company, a cooperative association incorporated with a capital of $50,000, divided into 10,000 shares. It diverts water from the Yakima River on the east side in sec. 7, T. 18 N., R. 18 E., about 9 miles northwest of the town of Ellensburg. The length is about 30 miles, and the area irrigated approximately 10,000 acres. It was built in 1887. As there are no flumes of importance to keep up, the maintenance cost on this canal is light.

OLSEN DITCH.

The Olsen ditch, sometimes spoken of as the Holme, Wool & Olsen, is not incorporated but is kept up by a few farmers who own the lands supplied. The water is taken from a slough near the intake of the Town canal. It irrigates about 12,000 acres. The first section of this ditch was built over thirty years ago, and was used for operating a sawmill. Some fifteen years ago it was extended for the purpose of irrigation. There is no company organization.

BULL DITCH.

The water for Bull ditch is taken from the tail race of the Ellensburg flour mill, or Shoudy ditch, and waste water which has been discharged into Wilson Creek. Two thousand two hundred acres of land

is supplied. The water is measured to consumers through a 2-inch orifice with a head of 4 inches above the opening. Twenty inches constitute a share. The assessments for maintenance are very small and shares have sold for $75.

TANEUM DITCH.

The Taneum ditch is the most important of the ditches taking water from creeks, and was built by a few farmers whose decreed rights entitle them to two-thirds of the water of Taneum Creek. The ditch runs in earth throughout its length, in places with a very steep grade. The water, which is not sufficient for the entire season, might be made to go much farther if the ditch were more carefully constructed so as to prevent such heavy losses. About 5,000 acres get water for one crop of hay.

The twenty-six shares of stock are held by forty different parties, and the water is supposed to be divided in proportion to the number of shares held.

SELAH-MOXEE CANAL.

The Selah-Moxee canal takes its water from the east side of the Yakima River in sec. 8, T. 14 N., R. 19 E., about 7 miles above the city of North Yakima. It supplies water for several hundred acres in Selah Valley, then passing a distance of about 5 miles around the point of the ridge dividing Selah Valley and the Moxee district, by flume, it enters the latter, where it supplies water for more than 4,000 acres.

The bottom width of the ditch through Selah Valley is about 10 feet, and it carries a depth of a little over 2 feet. The flume is 7 feet wide through most of the 5 miles, being somewhat larger at the upper end. Below the flume the section for several miles is about the same as through Selah Valley, gradually reducing at the lower end. The grade of the canal is from 1½ to 2 feet per mile; that of the flume about 4 feet per mile. The contract price for the construction of this flume (23,000 feet long) was $22,000 (lumber was about $9 per thousand at the time), but $3,000 or $4,000 more was put into it the first year, for foundations. The total cost of the canal is estimated at from $75,000 to $80,000. It is 26 miles long and was built in 1900

The canal is controlled by a stock company, the stock being divided into 6,000 shares, the intention being to have one share of stock for each acre of land under the ditch and to divide the water in proportion to the number of shares held by consumers. The canal is supposed to carry 0.1 cubic foot per second for each share.

Water rights originally sold for $25 per acre or per share, but have since been raised to $35. Land with water right sold for $60. The maintenance fee was $1.50 per acre up to 1904, but for 1905 and 1906

$2 per acre. In return for old rights, the landowners in Selah Valley get free water from this canal. Up to the present the management has been in the hands of the original stock company; but as the stock is now principally held by the farmers, the canal is to be turned over to them. The land is practically all under irrigation.

TAYLOR DITCH.

Taylor ditch is a private ditch built by the Taylors nearly thirty years ago. It is located on the west side of the Yakima River, and heads near Selah Station nearly opposite the intake of the Selah-Moxee canal. Its length is only about 4 miles. There is supposed to be about 1,500 acres under the ditch and 1,000 acres irrigated. This land is all low and much of it subject to subirrigation.

MOXEE AND HUBBARD DITCHES.

Both the Moxee and Hubbard ditches, owned and controlled by the Moxee Company, were built nearly thirty years ago, and supply water to several thousand acres of land belonging mainly to the above-named company. They are each about 10 miles long, with bottom widths of from 4 to 6 feet, and carry 18 inches to 2 feet of water, the grade of each being very light. Water is diverted from the river on the east side near the line between secs. 7 and 18, T. 13 N., R. 19 E.

Some land has been sold by the Moxee Company carrying with it water rights. Under the Moxee ditch contracts call for 1 cubic foot per second for 160 acres, while under the Hubbard ditch 1 cubic foot per second is allowed for 100 acres. The maintenance fee in both cases is $1 per acre per annum. Measurements to consumers are supposed to be made over rectangular weirs, but little attention is paid to the matter of distribution, as only a small part of the land is owned outside of the Moxee Company.

FOWLER DITCH.

The Fowler, sometimes called the "Last Chance" ditch, was built over twenty years ago. It takes water from the river on the east side near, but below the headings of the Moxee and Hubbard ditches, and follows a course through the Moxee district roughly parallel to the above ditches. In places all three run along hillsides within a space not over 200 feet wide.

This ditch supplies only a small area in the Moxee district, but an extension is now being built through Union Gap to irrigate 2,800 acres of land lying above the line of the Sunnyside canal. This will all be valuable fruit land. About 500 acres were more or less improved during the summer of 1906. The extension consists of about 2½ miles of 4-foot flume with a grade of 2 feet in 5,000; then several miles of ditch with 5-foot bottom and the same grade as the flume.

Besides the extension, the entire line of the old ditch is being worked over and enlarged. The cost of the extension is estimated at $50,000. Water rights will be sold for $50 per acre, or possibly more, and the annual maintenance fee will probably be $1.50 per acre.

Before discussing the canals of the lower Yakima Valley below Union Gap, a few of the more important ones taking water from the Natchez River will be described, as they more naturally belong to the North Yakima district.

SELAH VALLEY CANAL.

Of these the one heading farthest up the river is the Selah Valley canal, which takes water from the left side of the river in sec. 35, T. 15 N., R. 16 E., about a mile above the mouth of the Tietan River. It was built in 1890, is 21 miles in length, and irrigates 6,000 acres, while there are about 5,000 acres which could yet be irrigated by extension. The cost of the ditch is estimated at from $70,000 to $80,000. The land and water contracts of the company owning it stipulate that the right to the use of water shall be and remain appurtenant to the land, and that the amount of water used shall not exceed 1 cubic foot per second for 160 acres. A uniform maintenance fee of $1 per acre is charged.

WAPATOX CANAL.

The Wapatox canal is one of the old ditches of the Natchez Valley, incorporated in 1884. It heads in the Natchez River on the left bank opposite the mouth of the Tietan River in sec. 36, T. 15 N., R. 16 E. There are about 1,800 acres irrigated, and there is still a considerable area of irrigable land not yet under cultivation.

Within the last two years the canal has been enlarged for use as a power canal in addition to furnishing water to the former users.

GLEED CANAL.

The Gleed canal is owned by a number of farmers incorporated as the Natchez Canal Company. The diversion is made from the left side of the river in sec. 24, T. 14 N., R. 17 E. At about half a mile below the intake the canal divides into two branches—the lower one about 4 miles long and the upper branch 10 miles in length. About 400 acres are irrigated by the short branch and 1,400 by the upper line, and there are still about 1,400 acres which might be irrigated.

YAKIMA VALLEY CANAL.

The Yakima Valley canal, sometimes referred to as the "Congdon ditch," is one of the most important canals of the North Yakima district, and from an engineering standpoint possesses some noteworthy features. The diversion is made from the right side of the Natchez River in sec. 24, T. 14 N., R. 17 E. For several miles the

line follows along a steep rocky sidehill, which makes it necessary to maintain about 5 miles of flume. This is mostly of the trapezoidal, or California, style. In one place a tunnel 150 feet long was made through a rocky point, and across the canyon of Cowiche Creek near North Yakima the water is carried by two inverted siphons of redwood pipe each 32 inches in diameter and 900 feet long. The greatest head is 90 feet. The pipes are banded with half-inch rods. The difference in elevation between intake and outlet of siphons is 3 feet. The first pipe was built in 1894 and cost $2,500, the work being done by the canal company. The second one was built in 1903 and cost $2,500, the work this time being done by the pipe company.

The entire length of the canal is 22 miles, and its capacity about 75 or 80 cubic feet per second. It was built in 1894, but was considerably enlarged in 1903. The original cost was about $100,000, and the cost of improvements in 1903 amounted to $57,000 more. Lumber cost about $10 per thousand when the original flume was built, and $12 or $13 per thousand at the time the improvements were made. The annual maintenance fee, which was originally 30 to 40 cents per acre, is now $2 per acre.

The canal is owned by a cooperative company, with 4,200 shares, or 1 share for each acre of land under the ditch. All the land below the ditch is irrigated, but some water is now being pumped for adjoining lands lying above the canal. The land irrigated lies just west of the city of North Yakima in what is known as the "Nob Hill" district, and is now the most valuable in the Yakima Valley.

NATCHEZ-COWICHE CANAL.

The Natchez-Cowiche canal is another of the old ditches taking water from Natchez River. It was built by farmers in 1881. The head is on the right bank in sec. 9, T. 13 N., R. 18 E. About half a mile below the point of diversion it crosses Cowiche Creek and during the early part of the season gets most of its water from this source. Starting about 5 miles northwest of North Yakima, it runs southward, watering in the first 3 or 4 miles considerable gravelly bottom land; then the remainder of its 7 miles passes through some of the best land of the valley.

The stock of the company is divided into 240 shares and is owned apart from the land—that is, a shareholder in the company, perhaps, may own no land himself, but has the privilege of renting his share of water to some one who has land to irrigate. One share is supposed to be good for water enough for 10 acres of land, and some use but half a share where the land is in orchard, small fruit, corn, etc. As there is no flume to maintain, the annual cost of keeping up the ditch is small. The assessment per share in 1903 was only $3, or not over 30 cents per acre.

POWER CANAL.

The Power canal is the largest canal taking water from the Natchez River. It heads on the right bank of the river in sec. 10, T. 13 N., R. 18 E. This is primarily a power canal, and only about 250 acres of land is irrigated from it. The waste water is spilled back into the river. The length of the canal is 6 miles and its capacity about 200 cubic feet per second. It was built in 1890.

The Shanno and Broadgauge canals are small ditches, and, although having separate headings in the river, they run under the large Power canal and receive from it practically all the water they use. Only a small acreage of gravelly bottom land is supplied by them.

UNION CANAL.

The Union canal takes water from the Natchez River in two places about half a mile apart on the right bank in sec. 11, T. 13 N., R. 18 E. No claim was ever filed for it, but its use of water dates back to 1869. The company agrees to furnish 3,000 miner's inches to its shareholders and 40 miner's inches to outside parties.

The two branches unite about three-quarters of a mile below the upper heading, and in section 13 it crosses the wasteway of the Power ditch, from which it receives some water. From the Power canal to a point on Natchez avenue in section 18, a distance of about a mile, it is known as the Mill ditch. At this point about half the flow is diverted and carried down Natchez avenue in North Yakima. The remaining water in the Mill ditch is returned to the wasteway of the Power canal.

The stock of the company is divided into 69 shares, or about one share for each 40 acres under the ditch. About 2,300 acres of land is irrigated, 120 acres being inside the city limits of North Yakima, the larger part, however, being gravelly bottom lands lying just northwest of the city.

TOWN CANAL.

The Town canal is a small ditch owned by the city of North Yakima and used chiefly for irrigating shade trees. The heading is on the right bank of the Natchez River, near the Northern Pacific Railroad bridge. It irrigates about 640 acres.

NEW RESERVATION CANAL NO. 2.

New Reservation canal No. 2 is the first canal which diverts water from the Yakima River below Union Gap. It was built by the Government in 1903 to irrigate land on the Yakima Indian Reservation. The heading is located on the right bank in sec. 17, T. 12 N., R. 19 E. The canal is about 40 feet wide, and the proposed length is 65 miles,

with three laterals with a combined length of 25 miles. At present only 4½ miles of the main canal is completed. The grade is 1.5 feet in 5,000. In 1905 it diverted as high as 140 cubic feet per second.

OLD RESERVATION CANAL NO. 1.

Old Reservation canal No. 1 is at present the most important canal in operation on the reservation. It is 12½ miles long, carries about 150 cubic feet per second, and covers 17,000 acres, of which 8,000 or 9,000 acres are irrigated. It heads in sec. 28, T. 12 N., R. 19 E., and bears nearly due south.

OLD RESERVATION CANAL NO. 3.

Old Reservation canal No. 3 heads in sec. 28, T. 11 N., R. 20 E. It is only 4 miles long and diverts but a small amount of water. No claims were filed for these old reservation canals. This canal and the old Reservation canal No. 1 were built by the Government from an Indian fund derived from the sale of the Wenache fishery lands, which were at one time owned by the Indians.

GILBERT DITCH.

Gilbert ditch is a private ditch, also on the Indian reservation, taking water from a slough in sec. 19, T. 11 N., R. 20 E. It was built by men who have leased lands from the Indians, and at the expiration of the lease the ditch will belong to the lands through which it runs. The length is 7 miles and the area irrigated, 3,000 to 4,000 acres. No claim has been filed, but about 35 cubic feet per second of water was diverted during the season of 1904.

The Hatch ditch is another small private ditch on the reservation. It is 3 miles long and diverts less than 10 cubic feet per second from a slough in sec. 30, T. 10 N., R. 21 E. About 600 acres of land is irrigated.

THE SUNNYSIDE CANAL.

The Sunnyside is the largest canal in the Yakima Valley, or in the State, the maximum flow being over 600 cubic feet per second. The beginning of this canal dates back to the early nineties. It was undertaken by the Northern Pacific, Yakima, and Kittitas Irrigation Company, which on March 23, 1891, filed on 1,000 cubic feet of water per second to be diverted from the left bank of the Yakima River in sec. 28, T. 12 N., R. 19 E. During the hard times the company underwent many vicissitudes, and the canal was finally purchased by the Washington Irrigation Company, which owned and operated it until 1906, when it was sold to the Government.

The present canal at the intake has a bottom width of 30 feet, and for several miles carries a depth of from 5 to 7 feet. The grade at the

upper end is 1¼ feet in 5,000. This grade gave a velocity so high that it was necessary to place a number of checks in the canal in order to reduce it. The grade and bottom widths are both reduced on the lower part of the canal. The 12-mile extension, which was built in 1903, has a fall of only 1 foot in 5,000, and is 12 feet wide on the bottom. The intake of the canal is about 10 miles south of North Yakima, the length being 57 miles. The length of the lateral system in the aggregate runs into the hundreds of miles, the Snipes Mountain branch itself being larger than a majority of the other canals of the valley.

The total area under the present ditch is about 64,000 acres, and of this 32,000 acres or more are at present under irrigation. The Washington Irrigation Company formerly owned the odd sections of land under the canal. The land has been sold with water rights for from $35 to $90 per acre. For a number of years, however, the price of most of the land has been $60, while only that near Prosser was held at $90.

Water rights for several years past have sold for $30 per acre, and considerable water has been rented for nonwater-right land at $2.50 per acre per year. There has been a uniform maintenance fee of $1 per acre on nearly all water-right lands, but a few sales were made in the early days of the company with a 50-cent maintenance fee.

The original company bought the rights of the old Konnewock ditch, which, before the present canal was built, irrigated several thousand acres of land in what is known as "Parker Bottom." These lands were given a perpetual free water right. The contracts for water specified 1 cubic foot per second for 160 acres from April 1 to November 1, the company to deliver the water to the highest point of the land on which it is to be used and the farmers afterwards to maintain the laterals. The manner of distribution from this canal is discussed in another part of this report. (See pp. 45–50.)

PROSSER FALLS LAND AND IRRIGATION COMPANY'S SYSTEM.

This is the largest pumping system in the Yakima Valley. It furnishes water for both domestic use in the town of Prosser and for the irrigation of 1,300 acres of land in the vicinity. The pumping plant consists of two pumps, of two cylinders each, with inside diameter of 25 inches and 24-inch stroke, driven by two 48-inch turbines operating under a 12-foot head. The average discharge is about 15 cubic feet per second. This is forced through 1,800 feet of 28-inch steel pipe, discharging into a penstock from which it enters the canal. The lift is 100 feet. A short distance from the penstock the canal divides, one branch, 8 miles long, extending up the river and the other, 3 miles long, running in the opposite direction.

The water for operating the wheels is diverted from the south or right bank of the river at Prosser. A solid concrete dam has been

built across the river at this point, raising the water nearly 10 feet. A flume 650 feet long, 12 feet wide, and 10 feet deep carries the water to the turbines. The mean depth in the flume during 1904 was 6 feet and the discharge 205 cubic feet per second, 7 per cent of which passed through the pumps.

In 1903 water rights cost $75 per acre, with a maintenance charge of $1.50 per acre per annum. Under some of the earlier contracts 1 cubic foot per second was allowed for 120 acres, but later contracts allow only 1 cubic foot per second for 160 acres, during the season from April 1 to November 1.

KIONA CANAL.

The Kiona is a small canal heading in the left bank of the river about 4 miles west of Kiona, in sec. 10, T. 9 N., R. 26 E. The length is 9 miles, width 8 feet, and capacity 20 to 30 cubic feet per second. In 1904 there was about 1,800 acres of land irrigated, and by an extension 26,000 acres could be watered by this canal. The contracts specify 1 cubic foot per second per 100 acres, with a maintenance fee of $1.50 per acre per year.

KIONA IMPROVEMENT COMPANY'S CANAL.

The Kiona Improvement Company's canal is a small ditch only about 2 miles long, just across the river from Kiona. It serves for both power and irrigation, as all the water used for irrigation is lifted from it by current wheels, which it operates. In 1903 there were eight wheels in use, but only a few acres of land was watered. The canal was built and is owned by the Kiona Improvement Company, consisting of a few farmers. The discharge June 6, 1904, was 18.5 cubic feet per second. The canal is about 6 or 8 feet below the general level of the adjoining land.

THE GROSSCUP CANAL.

The Grosscup canal, 5½ miles long, was built in 1904 to irrigate lands on the farm of Mr. Grosscup. The water is taken from the left side of the Yakima River just opposite the intake of the Kennewick canal, the same diverting dam serving both. No water was used until 1905. Since then only a small amount of land has been irrigated.

KENNEWICK CANAL.

The original Kennewick canal was owned by the Yakima Irrigation and Improvement Company, composed of or backed by eastern capitalists. The canal, 8 feet wide and 20 to 30 miles in length, was completed in 1894 and operated for two years. Then, due to financial difficulties, it was turned over to an organized irrigation district, the old company taking the bonds of the district. The canal was aban-

doned after the two years above mentioned, and the bonds of the district were not redeemed. Later the original company perfected its title to the property and sold it to the company which now owns and operates it.

In 1902 the canal was entirely reconstructed and enlarged at a cost of $202,900. The work was done by day labor, the wages of laborers being $2 per day, teams $2.25, and foreman $2.50. The bottom width at the head is 18 feet and the length of the main canal is 35 miles, with a grade of 1 foot in 5,000. The depth of water carried near the head is about 4 feet, and the discharge is between 125 and 150 cubic feet per second.

The diversion is made from the right bank in sec. 3, T. 10 N., R. 27 E., about 10 miles above the mouth of the river. The canal runs close to the Yakima River most of the way from the point of diversion to the mouth of the river, then continues from a quarter of a mile to a mile back from the Columbia down as far as Kennewick. Here the main canal swings back farther from the river, reaching, a few miles below town, a distance of about 4 miles at the widest part of the district, then again gradually circling around to the river at the lower end of the valley, 12 or 15 miles below Kennewick. A lateral is taken out near Kennewick and extends for several miles, keeping closer to the river. Water was first turned into the new canal in the spring of 1903.

The acreage intended ultimately to be served by the system is 12,400 acres, of which the irrigation company owned or controlled the odd sections. This land in its raw state with a water right sold three years ago at from $30 to $75 per acre. In 1906 prices ranged from $65 to $400 for the same land, while with improvements it is now valued at from $150 to $750 per acre.

A little more than 4,000 acres of it was irrigated in 1906. The price of water rights have advanced during the past two years. At present the minimum price is $50 per acre and the maximum is $75. The contracts allow 1 cubic foot per second for 160 acres, with an annual maintenance charge of $1.50 per acre. This fee was $1 per acre under earlier contracts.

BENTON WATER COMPANY'S CANAL OR "AMON CANAL."

The Benton Water Company's canal, or "Amon canal," was built in 1905 by the Benton Water Company. It heads on the left side of the river about 5 miles below the intake of the Grosscup ditch. The first 2½ miles has a bottom width of 20 feet, with side slopes 1 to 1, grade 1 foot per mile, and is intended to carry water 4 feet deep. The next 1.3 miles is 15 feet wide on the bottom, with side slopes 1½ to 1, and the same grade; then for 3¼ miles it is 7 feet wide with the same grade and slopes. In this distance there are two flumes—

one 2,200 feet long and the other 2,600 feet, with 5-foot bottoms, 3-foot sides, and the same grade as the ditch. The canal divides near the seventh mile into two branches—one 3¼ miles long and the other 3 miles long. In one branch there is a flume 1,328 feet in length, with 5-foot bottom and 2-foot sides. The grade of both branches, including the flume, is 1 foot per mile. It was the original intention of the company to build a 20-foot ditch to about the sixth mile and there to install a power plant, the ditch at this point being 26 feet above the river.

The company bases its claim for water on an old filing for 200 cubic feet per second made by Nelson Rich, October 17, 1892, and upon an additional claim for 200 cubic feet per second which it filed in February, 1905. About 2,500 acres of land was owned by the canal company. This has been selling for from $85 to $150 per acre with water right, while some small tracts near the town of Richland have been sold for $300 per acre. The contracts allow 1 cubic foot per second for 160 acres and call for an annual maintenance fee of $1 per acre. Water rights for land not owned by the company are sold at $25 per acre. The land under this ditch is similar to that at Kennewick, being either very sandy or a sandy loam with underlying gravel.

ORGANIZATION AND MANAGEMENT.

A large number of the smaller ditches have no formal organization, but the majority of those diverting 20 cubic feet per second or more are regularly organized and are usually incorporated. The cooperative stock company is the commonest form. The stock is usually divided into shares, some companies having one share of stock for each acre to be irrigated, others having one share to 10 acres or more. The Cascade Canal Company was organized by men who owned the land to be irrigated, each taking a certain amount of stock, and no stock was for sale to outside parties. Other companies—the Selah-Moxee Company, for instance—owned or controlled the land, and with each tract sold gave a certain amount of stock in the ditch, this stock being appurtenant to the land. A few of the canals also, of which the Natchez-Cowiche is an example, have sold stock to parties not owning land. Such parties lease water to landholders in such way as they see fit or transfer it at will.

Expenses for maintenance and operation are met by annual assessments upon the stock, and water is supposed to be distributed in proportion to the number of shares held.

There are also a few canals owned and operated by regularly incorporated canal companies, which sell water rights or lease water without transferring to the purchaser any share or interest in the canal system itself. Such a company merely contracts to deliver water under

certain conditions, exacting a fixed maintenance fee, and the water users have no voice in the management. The Kennewick canal is one of this kind and the Sunnyside canal under the former management was another. Superintendents or managers are appointed by the owners.

DIVERSIONS.

On account of the ease with which water can in most places be taken from the streams of the Yakima Valley, there has been very little attention paid to the matter of diversion works, and throughout the entire length of the valley it would be impossible to find a single canal with strictly modern means of diverting water from the rivers or regulating the flow through the headgates.

Nearly all the canal companies adhere to the old practice of building loose rock wing dams to turn water into their ditches when the supply gets short, evidently believing it better to repeat this operation each year than to spend a few dollars more at one time in providing concrete structures that would be there forever. The Prosser Falls Company is the only one in the valley which at present has a permanent structure of this kind. The Washington Irrigation Company maintained for several years a dam at the head of the Sunnyside canal, which consisted of steel brackets and flash boards. In the fall of the year the flash boards were taken out and the brackets turned down flat upon the concrete base to which they were attached, and the next season when the water began to get low the brackets were raised and the flash boards replaced. This dam was never altogether satisfactory, however, on account of the difficulty usually experienced in raising the brackets, which work was also often accompanied by considerable danger to the men, several narrow escapes from drowning having been experienced. The Government is now replacing this structure by a solid concrete dam 7 feet high, which will be completed at an early date. The Northern Pacific Irrigation Company maintains a fairly good rock-fill dam across the river at the intake of the Kennewick canal, and a timber dam was built by the Benton Water Company in 1904 to divert water to its canal a few miles below.

As most of the canals were built years ago when lumber was cheap, that was the logical material of which to construct headgates and other irrigation structures; consequently scarcely anything else is found to-day in works of this kind, but with common lumber now at $17 per thousand it would appear to be poor policy to continue its use. The headworks are almost universally of very crude design, with no modern appliances for regulating the gates, which are generally operated by means of levers. The only headworks designed and constructed with any degree of permanence are those of the New Reservation, the Sunnyside, Kennewick, and Benton Water Company

canals. Those of the Sunnyside canal are being reconstructed by the Government and when completed will be the only strictly modern works of the kind in the valley.

The following tables show the diversions from the Yakima and Natchez rivers during the irrigating season of 1904:

Discharge of canals from Yakima River, 1904.

[In cubic feet per second.]

Canal.	Apr. 16–30.	May.	June.	July.	Aug.	Sept.	Oct. 1–15.	Average.
West Kittitas	50.0	50.0	53.0	48.8	52.2	55.0	56.0	52.0
Town	100.0	110.0	122.0	124.0	127.0	116.0	.....	116.0
Olsen	.....	.....	.....	.....	.....	.....	.....	14.0
Selah-Moxee	98.0	77.8	76.9	69.5	78.2	72.6	39.0	74.9
Taylor	.....	.....	.....	.....	.....	.....	.....	11.0
Moxee	17.0	18.0	18.3	10.3	35.4	30.7	4.0	21.1
Hubbard	18.0	31.0	24.1	23.5	37.4	18.9	15.0	24.8
Fowler	25.0	34.0	22.0	23.6	23.0	33.0	16.0	25.9
Granger	.....	.....	.....	.....	.....	.....	.....	18.0
New Reservation	20.0	27.0	49.1	86.4	69.0	73.6	50.0	56.4
Old Reservation	100.0	130.0	145.0	164.0	147.0	100.0	90.0	130.0
Reservation canal No. 3	.....	.....	.....	.....	.....	.....	.....	10.0
Sunnyside	496.0	529.0	561.0	585.0	610.0	524.0	456.0	547.0
Gilbert	25.0	40.0	58.9	47.9	28.6	17.0	10.0	35.1
Hatch	.....	.....	.....	.....	.....	.....	.....	8.0
Prosser Falls	190.0	210.0	214.0	212.0	201.0	195.0	209.0	205.0
Ledbetter	.....	.....	.....	.....	.....	.....	.....	2.0
Kiona	17.0	20.0	20.0	21.1	19.0	20.3	21.3	19.9
Kiona Water Supply Co	.....	.....	.....	.....	.....	.....	.....	19.0
Kennewick	53.6	85.5	101.0	117.0	126.0	126.0	124.0	107.0
Total	.....	.....	.....	.....	.....	.....	.....	1,622.0

Discharge of canals from Natchez River, 1904.

[In cubic feet per second.]

Canal.	Apr. 16–30.	May.	June.	July.	Aug.	Sept.	Oct. 1–15.	Average.
Sinclair and Cobb[a]	.....	.....	.....	.....	.....	.....	.....	5.0
Selah Valley	45	59.0	83.3	69.5	86.7	80.8	60.0	72.0
Small ditches (combined)	.....	.....	.....	.....	.....	.....	.....	15.0
Wapatox	20	40.0	37.2	29.0	37.0	26.1	14.8	31.2
Cox	.....	.....	.....	.....	.....	.....	.....	4.0
Upper Scott	.....	.....	.....	.....	.....	.....	.....	7.0
Lower Scott	.....	.....	.....	.....	.....	.....	.....	10.0
La Fortune	.....	.....	.....	.....	.....	.....	.....	7.0
Laswell	.....	.....	.....	.....	.....	.....	.....	10.0
Yakima Valley	40	46.8	55.3	62.5	77.5	60.8	43.4	57.4
Schuller and Rhodenbach	.....	.....	.....	.....	.....	.....	.....	6.0
Clark	.....	.....	.....	.....	.....	.....	.....	5.0
Lowery	.....	.....	.....	.....	.....	.....	.....	15.0
Kelly	.....	.....	.....	.....	.....	.....	.....	30.0
Gleed	40	65.0	61.1	55.9	69.4	38.8	28.0	54.2
Morrisey	.....	.....	.....	.....	.....	.....	.....	6.0
White and Leach	.....	.....	.....	.....	.....	.....	.....	8.0
McCormick	.....	.....	.....	.....	.....	.....	.....	5.0
Shearer-Chapman	.....	.....	.....	.....	.....	.....	.....	6.0
Natchez-Cowiche	30	42.0	38.9	38.9	53.5	29.1	24.0	38.4
Broadgauge	4	5.5	[b] 17.0	[b] 15.9	[b] 16.3	[b] 10.0	[b] 8.0	[b] 11.8
Power	170	174.0	178.0	176.0	189.0	199.0	196.0	183.0
Shanno	20	21.0	29.1	[b] 30.0	[b] 30.0	[b] 19.0	[b] 15.0	[b] 24.4
Union	35	41.7	39.0	37.3	36.9	32.0	30.0	36.6
Town	10	14.0	12.3	12.5	14.5	11.4	10.0	12.5
Total	.....	.....	.....	.....	.....	.....	.....	660.0

[a] From Tieton River.

[b] From Power canal.

OPERATION OF CANALS.

With the smaller farmers' ditches operation is a very simple matter. Water is turned in about the first of April and so long as enough keeps coming little further notice is given to it. If the supply for some farmer gets short he may take a walk up the ditch to see what has happened, or turn more into it, and if more comes than he can use, the remainder will be turned into a wasteway or over the river bank, and that is all there is to it. With the larger ditches with flumes and side-hill construction, or miles and miles of laterals, the matter of operation is not at all simple, although probably not so complicated as the running of a railroad. With the close of every irrigation season comes a feeling of great relief to those who have been responsible for the satisfactory operation of a canal system and for the continuous delivery of water to hundreds of users, who all want what is coming to them and often more. This responsibility in most of the larger companies falls upon a general manager, the canal or water superintendent, and ditch riders or patrolmen. In some instances the canal superintendent may be general manager also.

The superintendent has general supervision of all field work, directs the regulation of water in the canal, instructs the patrolmen in matters pertaining to the distribution of water or their other duties, receives their reports, attends to necessary repairs, and at all times should know as far as possible the exact condition of the entire system from beginning to end.

The patrolmen are each assigned a certain definite "beat" or section of the system to look after, and it is the duty of each to ride or walk over the section of canal included in his beat at least once a day, inspecting the canal in order to detect leaks or other irregularities, to set the headgates of laterals when necessary, and to report the condition of his section each day to the superintendent.

In connection with this subject it may not be out of place to mention some of the difficulties incident to the operation of canals in the Yakima Valley and to show how certain obstacles are dealt with.

One of the most perplexing problems which some of the canal companies have, and one which causes no end of anxiety throughout the season of irrigation, is that of maintaining long lines of flume. To one not familiar with canal operation it would seem that the flumes should require less attention than almost any other portion of a canal system, but such is not the case so far as the canals of the Yakima Valley are concerned. A properly constructed flume while new does not ordinarily give much trouble, but the life of wooden structures of this nature is necessarily short, especially parts which are exposed to the atmosphere and are more or less wet most of the time. With the best of construction it is a matter of but three or four years at the

most until repairs more or less extensive are necessary each year, and from that time the matter of keeping up the flume is one of increasing anxiety, annoyance, and expense with each succeeding year.

As a general thing the flumes are built on steep, rocky or gravelly hillsides where ditch construction is impossible or would be expensive far beyond the means of the ordinary company. In such situations a thoroughly secure foundation is seldom found, and up to the present a flume that will not leak has never been built in the Yakima district.

From the combination of leakage and insecure foundations arise the chief difficulties with the ordinary wooden flume. Even a small leak, if continued for any length of time, will usually soak up the foundation of the structure until a settlement occurs. With the settling of the structure the leak is increased until finally, if not attended to, a slip or landslide is likely to occur, and down the hill will go perhaps a hundred feet or more of the flume, which will require several hundred dollars to replace. This loss may not be all. If such a break occurs in the midst of the irrigation season when crops are in need of every drop of water obtainable, the loss to farmers may be enormous. And it is usually at such a time, when the demand for water is greatest and the canals are running under heaviest pressure, that disastrous breaks occur. Instances of this kind in connection with the operation of the various canals of the valley are too numerous to mention.

Another serious difficulty is the rapid shrinking and drying out of flumes if water is shut off a few days, and it often requires a week or more to get with safety the same head of water into them that they were previously carrying. It is, therefore, highly essential that the flumes receive the very closest attention and daily inspection, and most of the canal companies keep an extra force of men or oakum squad constantly at work calking leaks and looking after such structures during a large part of the season. In some instances night watchmen are employed.

Two of the large flumes—one in the Ellensburg district, and one near Kennewick—are so situated that the loose gravel or drifting sand from hillsides above, by accumulating against the upper sides, are a menace to the safety of the structures. At Kennewick, troughs or sluice boxes have been placed between the flume and the hillside so as to catch the drift sand, and a small head of water is occasionally turned into them from the flume, sluicing the sand out beneath. (Pl. II, fig. 1.)

The practice of applying coal tar, asphaltum, or a combination of the two, to the interior of flumes, with a view to preserving the material and preventing leakage, has been adopted to some extent, and under certain conditions its use might be recommended. The Selah-Moxee Company of North Yakima did considerable work of

this kind on their flume during the winter of 1905 and 1906. Mr. John Neuenhof, canal superintendent, kindly supplied the following notes with reference to method of applying the asphaltum:

The flume is 7 to 8 feet wide, 4 feet deep, with cross-ties every 4 feet.

First, it was necessary to remove cross-ties, leaving every ninth one. This was done in order that the work could be done more readily.

Second, all deposits of silt were cleaned out with shovels.

Third, the flume was swept with steel barn brushes, then with heavy brooms and finer brushes, the intention being to remove all dirt before the application of the asphaltum.

The asphaltum was heated in a special heater, or vat and furnace combined, which could be moved right along in the flume ahead of the work. The material should be heated until it begins to puff, and it is important that just the right temperature be attained. If it is too hot the brushes are burned, and if not hot enough it will not spread freely. The heated material was dipped from the vat with a large iron ladle and emptied into buckets, from which it was applied with mops. Some of the mops were made of raveled cotton rope, but hemp mops stood the heat better and wore longer. One of these would last three or four hours.

The working force consisted of two men to take off cross-ties and replace them; three sweepers; two moppers; four men for brushing, distributing lumber, wheeling asphaltum, and general work; and the foreman, who attended to the heating of material.

In one day 960 feet of the flume was treated, the material being moved half a mile with a wheelbarrow. Altogether about 5,000 linear feet, or 17,500 square feet, of flume was painted in this way. Thirty-six barrels of asphaltum were used. The wages were 20 cents per hour for all men except the foreman, who received $75 per month. Asphaltum cost about $6 per barrel.

The Yakima Canal Company uses a mixture of asphaltum and coal tar, and the Northern Pacific Irrigation Company uses coal tar alone. The methods of application are similar.

Mr. Neuenhof does not recommend the treatment of old flumes, as experience shows that the asphaltum or tar will not adhere evenly to old material, and, unless the lumber is quite dry, it will blister and peel off in large sheets. For new structures and dry lumber the use of either tar or asphaltum may be recommended.

Although many of the difficulties of canal operation are associated with the flumes, the ditches also come in for a large amount of attention, and, as in the case of flumes, breaks are one of the very serious things that have to be guarded against. On some of the canals they are not an uncommon occurrence, and even upon the largest canal of the Yakima Valley it has been considered a very successful year

FIG. 1.—FLUME NO. 1, KENNEWICK CANAL. SHOWS SIDEHILL CUT THROUGH CEMENT GRAVEL TO FORM BENCH FOR FLUME.

FIG. 2.—SEEDING NEW SAND LAND TO ALFALFA TRACT IN SECTION 16, TOWNSHIP 8 NORTH, RANGE 30 EAST, KENNEWICK. SHOWS DISTRIBUTING FLUMES.

that has not at least one bad break to be recorded. These as a rule have resulted in no great damage to property other than that of the canal, but often result in the loss of crops to quite an extent.

To repair such breaks is sometimes rather a difficult undertaking. When they occur upon hillsides, about the only thing to do is to replace the washed-out portion of the canal by a flume. On the Sunnyside canal they have usually been repaired by cutting a new channel on the upper side, thus carrying the water past the break, the same as trains are sometimes run on temporary tracks to get around a wreck on a railroad. It is seldom considered advisable to attempt to replace the washed-out portion of a levee with a new bank, as experience has shown that it will not hold. A disastrous experiment of this kind was made on one of the large canals in July of 1906, which resulted in the loss of water to crops for several days longer than would otherwise have been necessary.

Many of the worst breaks have been caused by heavy rains or cloud-bursts which pour great volumes of water from the hills into the canals, overflowing and breaking the banks, but perhaps more of them have been the result of smaller agencies. Burrowing rodents are a very great nuisance, and perhaps 75 per cent of the breaks have been caused by ground squirrels or badgers which have made holes through the banks. The extermination of these pests usually devolves upon the patrolmen, who resort to traps and poison, but sometimes extra men have to be put on especially for this work.

The growth of weeds, especially thistles, along the canals is another nuisance, the growth in places being so dense that it is very difficult to ride a horse along the banks. Besides being altogether obnoxious to the canal management, the weeds are equally offensive to the farmers; and as the canals and laterals are an excellent means for the dissemination of seeds more strenuous measures should be used to destroy them. At present too little attention is given to this matter, and as a result the nuisance is spreading each year.

Another very serious obstacle, and one which interferes in a greater or less degree with the successful operation of practically every canal in the Yakima Valley, is the prevalence of aquatic plants wherever there is a low velocity. Several kinds are found in the Yakima canals, one of the worst of which is the water buttercup (*Ranunculus aquatalis*). In places this chokes up nearly the entire section of a ditch from the bottom to the surface of the water, where the small white bloom occurs, and so effectually does it check the velocity that scarcely any current can be detected.

Most of the canals have a light grade, and with this uniform the lowest velocities occur toward the lower ends where the cross section is less and the volume smaller. Naturally, then, it is toward the lower ends of the canals that aquatic growths are most troublesome, and it

is during July and August that their effect upon the flow in the canals is most marked. Later in the season they break off and float down the stream, so that late in October the channels are again more nearly in their normal condition. In midsummer the capacity of some canals is reduced as much as 50 per cent from this cause.

As yet no altogether satisfactory or effective means has been hit upon for removing or preventing these growths. One way that has been tried in the Moxee district is to get into the ditches and mow the plants with scythes. This has to be done when the water is flowing, as otherwise they lie flat upon the bottom and can not be handled in this way. Another method has been to drag brush, chains, or something of the kind up through the ditches to break off the weeds, but, as it is difficult to get horses along many of the smaller canals in such a way as to render their use effective, this method is not just what is needed, so as the matter stands this is one of the problems of operation which remains to be solved.

If the velocity of a canal is so great that the growth of aquatic plants does not occur, there is likely to be the question of erosion of the banks to be considered, especially upon short curves. This problem is more serious on the Sunnyside canal than upon most others of the valley.

This condition has given rise to a rather novel method of riprapping. Stone suitable for this purpose is not to be had, and it has been necessary to use such material as is readily obtainable. This is sagebrush. Stakes are driven into the bottom and sides of the canal where the cutting occurs; a rough network of baling wire is fastened to them, into which is woven the riprap of sagebrush. This catches silt and small particles of drift of various kinds and forms quite an effective means of preventing further erosion.

DISTRIBUTION OF WATER FROM CANALS.

The overabundance of water which has in past years been available throughout the Yakima Valley accounts for the very crude and totally inadequate means for the just and equitable distribution of water among irrigators. It is a deplorable fact that not a single canal system in the entire length of the Yakima Valley is to-day in such a condition that even an approach to equitable division and distribution can be made. Many of the smaller canals are without any means for measuring the water used, and many of the larger ones on which some attempts at measuring have been made might almost as well be without anything, for, on account of the crude construction, lack of uniformity in placing, and in the conditions under which they operate, such devices as are now in use are of practically no value for taking measurements even approximately

correct. They serve merely as rough guides for the ditch tenders, helping them to compare the discharges of individual deliveries from day to day, and also help the consumer to imagine he is getting his just portion of the water.

Several of the largest irrigation companies contract to supply definite amounts of water to consumers, but without exception these companies have in the past delivered many times the contract amounts. Others of the large companies are supposed to give a certain proportion of the flow, depending upon the amount of stock held by the consumer. So long as every irrigator gets as much as he can use it makes no material difference to him whether the distribution is uniform, or whether he gets more or less than some other farmer, but let the supply run just a little short and then it is very desirable to know more definitely what is being delivered. It is then that every farmer accuses his neighbor of stealing his water, or the ditch tender of favoritism toward certain parties, and it is safe to say that this same matter of the distribution of water is the cause of more animosity, strife, and dissension among the farmers, and friction between them and the ditch riders or canal managements than any other one thing in connection with irrigation work.

While in the past the companies have been more than liberal with water, and have, where contracts called for 1 cubic foot per second, given two to ten times this amount, and the cooperative ditches have had sufficient to satisfy all, these conditions can not go on forever, and it is not right that they should. With the thousands of acres still dry, which with water would make homes for hundreds of families, it is not fair to the Yakima Valley or to the State of Washington that the extravagant and wasteful methods of irrigation which have prevailed in the past should continue indefinitely; and they will not.

One of the first steps in the organization of a system for distribution should be to provide means whereby the canal superintendent may know more about the canal in his charge. He should be provided with a current meter, or at least have some means of determining how much water is being diverted by his canal, and should further be able to know what becomes of it afterward. He should be able to know from day to day just what is being drawn from the canal by each of the laterals, and the number of acres watered by each one. A careful record of distributions should be kept throughout the season, as such records will be valuable as guides for future division, will give information regarding the duty of water, and may also be worth something as evidence in cases of dispute which often arise over water distribution.

In order to make such a system effective the canal superintendent at least, and if possible the patrolmen or ditch riders as well, should

have a clear understanding of the common ways of measuring water over weirs or by miner's methods, and be able to install devices of this kind.

The matter of providing and maintaining satisfactory measuring devices is the most perplexing and difficult one to be encountered, and, as was stated above, nothing of the kind has yet been made to satisfy all conditions. The miner's method has been the commonest means of measurement in the past in this valley. At least a half dozen different styles of boxes have been or are being used. There seems to be an almost utter lack of uniformity between them, and even on the same canal it would be difficult to find any two boxes with governing conditions entirely similar, so that there are as many different miner's inches as there are boxes.

The court of Kittitas County has defined the miner's inch as the amount of water which constantly flows through an opening 1 inch square, through a plank 1 inch thick in the side of a box in which still water is maintained at a constant depth of 4 inches above the top of the opening. In some other parts of the valley the boxes are made with orifices 2 inches high, and have the water stand 6 inches above the opening. Boxes of this type are now in use under the Sunnyside canal in Parker Bottom, where water is taken out to supply lands which were formerly supplied by the old Kennewick ditch. The orifice is made 2 inches high and usually about 2 feet long, and there is an adjustable slide by which the length of the opening may be regulated. The size of the boxes is not uniform, but usually they are about 4 feet long and from 18 inches to 2 feet wide, with an iron plate overfall extending the length of the box on the side opposite the opening for discharge. The water is turned into the box until it is level with the crest of this overfall, and the headgate is then locked. Two of the most common defects found with this mode of measuring are, the failure to check the entrance velocity and to provide free fall at the outlet. The water enters most boxes with a rush, sometimes with a sheer drop of a foot or more, and it is the rule rather than the exception with the Kennewick boxes to find the water in the lateral backed up so as to at least partially cover the orifice through which the surplus is wasted.

The Hubbard, Fowler, and Moxee canals near North Yakima use rectangular weirs for measuring water supplied to farmers. These are made with no end contractions and consist merely of a plank with beveled edge set in a short flume or box. The boxes are built 1 foot high, 2 feet wide, and of a length sufficient to reach through the bank of the canal, usually about 10 to 14 feet. A gate set at the end on the inside of the canal bank regulates the entrance of water which passes over the weir board near the other end. This is 6 inches high, and in the boxes noted was set with the beveled side upstream. Such

boxes can be of no use whatever for making accurate divisions of water and are described merely to show one of the many very crude methods now in use.

Three canal systems have adopted the Cipolletti weir, which, if properly installed and attended to, is perhaps the best method now in use for making careful measurements of water, and we would recommend its wider adoption. However, there are a number of conditions which it is necessary to observe in connection with the use of this weir in order that the results may be relied upon, and, so far, not sufficient care has been taken to keep the weirs in proper condition.

(1) The length of the weir should be sufficient to permit all water needed to pass over it without the depth in any case exceeding 2 feet.

(2) The end and bottom contractions of the weir must be complete. To secure this, (*a*) the crest of the weir must be horizontal and the sides must be inclined with a slope of 1 horizontal to 4 vertical; (*b*) the crest of the weir must be perpendicular to the axis of the ditch; (*c*) the upstream edge of both crest and sides of the weir must be sharp, and the walls cut away therefrom to prevent the creation of a vacuum; (*d*) the distance of the crest of the weir from the bottom of the flume must be three times the maximum depth of water intended to pass over the weir, and the distance from the end of the crest of the weir to the sides of the flume must not be less than twice the maximum depth of water to flow over the weir.

In the spring of 1904 the management of the Sunnyside canal undertook to improve methods of distribution, and as this is the largest system now in operation in the Yakima Valley, some further description will be given regarding what has been done.

DISTRIBUTION UNDER SUNNYSIDE CANAL.

The main canal is 57 miles in length and carries between 600 and 700 cubic feet of water per second. One hundred and fifty to two hundred diversions are made from the canal. These diversions range in amount from 1 cubic foot per second, or less, up to 15 or 20 cubic feet per second, and supply laterals from a quarter of a mile to 10 or 12 miles long. These laterals in general follow the crests of ridges or elevations, roughly at right angles to the main canal. The farms average about 20 acres, and in most instances each farm receives from the laterals an individual delivery of water, for the measurement of which in most cases weir boxes with adjustable gates have been supplied at the company's expense. Many of the laterals in this way supply water to from five to thirty different farms. The Snipes Mountain lateral, over 12 miles in length, with a number of large sublaterals, constitutes a system larger than that of many independent canals of the valley.

With this great volume of water to be equitably divided among so many different laterals and then to be again fairly distributed to the hundreds of individual farms, the magnitude of the undertaking should at once be evident and the need of system doubly apparent. In the endeavor to establish an adequate system for such distribution, the work of placing Cipolletti weirs at the heads of laterals and weir boxes at points on the laterals where individual deliveries are made, was begun a number of years ago. This was an excellent beginning, and the company finally succeeded in having at one time means of measurement for a majority of its deliveries, but the entire plan was never carried out.

In the spring of 1904 the writer became associated with this company in connection with the work of distribution, and an attempt was made to further perfect the methods which had been in use. The weirs at the heads of the laterals had received no attention and scarcely any were in shape for use, so the first step taken was to repair the old weirs where they existed and place new ones in laterals where they were lacking. As was explained before, the miner's method is used for measuring water along the first 8 or 10 miles of the canal to the old Kennewick lands. Little could be done with these boxes except to level them up.

The repairs required on the weirs consisted principally in cleaning or enlarging the pools or channels above them in order to give the proper contractions and to reduce the velocity of approach and to raise the crests of the weirs so as to provide a free fall for the discharge. To get the necessary fall often required that the crests of the weirs be placed within a foot or less of the level of the water in the main canal at ordinary stages. In order that the supply need not be entirely shut off when only a small head was carried in the canal, provision was made whereby openings could be made beneath the crests of the weirs. It is often necessary to get water into such laterals early in the spring or late in the fall when not enough is in the canal to allow the weir to be used. Here is one of the most serious difficulties encountered in connection with the use of weirs, or for that matter any other practical means of measuring diversions. The farmers wish to irrigate all the land possible and locate their laterals or head ditches just as high as they can and get water into them, which does not leave the fall which a weir requires. The miner's boxes need still a greater margin, and for discharges of only a cubic foot or two per second it is not practicable to use rating flumes, so such diversions will have to be changed or, if continued, be regulated by guess as they have been in the past. In developing new irrigation districts this difficulty should be guarded against by prohibiting the diversion of water from the canal at a height so near

the water level in the canal as to make the measurement of the water impossible.

In some places where the lands adjoining the canal sloped away more rapidly the weirs had ample fall, but were set so close to the outlet from the canal and so much below the level of the water in it that the water would shoot through the weir at a very high velocity. Such weirs were raised or baffle boards were put in the channels near the outlets from the canal so as to check the velocity.

To provide a convenient means of measuring the depth of water passing over the weirs 3 by 4 inch posts about 3½ feet long were set in the channels several feet above the weirs, with the tops projecting 6 inches to a foot above the water which would ordinarily pass over the weirs. To the side of the posts blocks were securely nailed so that the tops would be just level with the crests of the weirs. The depths on these blocks then gave the depths passing over the weirs. Later, painted scales graduated to quarter inches were tacked to the sides of the posts so as to show the depths on the weirs. This made it possible for the patrolmen to read these without dismounting at each lateral.

After providing the means of making measurements of diversions, the next step was to start a system of records. In order to do this each lateral was numbered. If the diversion was made at a point 10.3 miles below the intake of the canal the lateral was designated as lateral No. 10.3, and so on. This system not only describes the location of each lateral but permits the establishing of new laterals without interfering with the numbers of others. On the headgate structure of each lateral was nailed a white block 1 by 6 by 8 inches, upon which the number was stenciled in large figures with black paint.

The patrolmen were supplied with weekly report cards, upon which was recorded daily the depth of water passing over each weir of his division. At the end of the week these cards were forwarded to the office at Zillah, where the data were placed upon monthly report sheets and filed.

That there might also be some check upon the water in the main canal, a gauge rod was placed at the beginning of the "beat" of each patrolman, and daily records of these gauges were included upon the weekly cards; but as these were to give daily the flow in the canal at these points, the gauge heights were telephoned to headquarters each morning.

These gauges, with the exception of the one at the intake of the canal, were placed in wooden boxes set in the canal banks, the purpose of this being to have the water quiet in order to permit a more accurate reading. The box at the head of the canal is made of concrete.

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Practically all the work of actual distribution is attended to by the patrolmen. They regulate the gates which supply the laterals, and also have to look after the division of the water to the ends of them. The measuring boxes, through which the individual deliveries are made, have never been kept in proper repair, so that the division of the water after leaving the canal is largely a matter of judgment on the part of the patrolmen. The acreage supplied by each lateral was ascertained as far as was possible without making actual surveys, and this information was of much value in the distribution. This is one matter which should be determined carefully. However, it frequently happens that a farm may receive water from two or three different laterals, which makes it difficult at times to find out just the exact number of acres served by each. It is necessary especially for the patrolmen to know the number of acres supplied from each box in his charge.

As the work is divided at present there are ten regular patrolmen in charge of the Sunnyside canal system, and over them is a canal or water superintendent. Upon these 11 men rests the responsibility of distribution. With so much territory to cover it is not possible for a patrolman to go over the main canal each day and also inspect the deliveries on all the laterals of his beat; consequently no great amount of attention has been given to the careful division of water from the laterals except during the month or two when water is scarce. At such times a few extra men are sometimes employed for this work. In the early part of the season, when there is plenty of water, if some man down at the end of a lateral asks for more water the patrolman will turn a larger head into the lateral, trusting that it will go through to the end where it is wanted. However, if instead of turning more water into the lateral he had gone along down it and cut the other farmers' supplies to what they were entitled to he would have found at the end more water than the man there could possibly use. By such a system as this enormous quantities of water are wasted each year. If the water supply of the farmers were to be cut down in each case to what the contracts call for and an attempt made to accurately measure out this quantity in every instance, a small army of men would be required to handle the distribution and keep the measuring weirs in proper condition. For this reason we believe that better and more satisfactory results in every way would obtain if the matter of dividing the water after being measured out at the heads of the laterals were left to the farmers themselves. The water contracts call for a continuous flow of water, and this method of delivery has almost universally been adhered to, not only under this canal, but on all others in the Yakima Valley. It is believed, however, that farmers here would find it more economical not only in water but in labor, and in every other way, to adop

methods of rotation in the use of water, as has been done in other parts of the West, where it has been found necessary in order to get the greatest possible good from a limited water supply. Any farmer who has had any experience as an irrigator knows the saving in labor that comes from having plenty of water to work with. A man may spend a week with a small stream in attempting to wet up his alfalfa, while if he could have borrowed equal amounts from two or three of his neighbors on the same lateral the job might have been done in two days. Farmers on a few laterals have learned this and are taking advantage of it by rotating or exchanging water in this way, thereby saving themselves a vast amount of unnecessary labor, but most of them insist upon having their little stream all the time, and if by putting a few laths in a drop or checks of some kind in the lateral they can increase the head of water in their measuring boxes it is the neighbors' loss and their gain. In this way there is constantly more or less strife and friction between neighbors, or farmers and ditch riders, and it will continue to be so as long as the present methods continue and it is necessary to have a lock on every man's measuring box.

To make such a radical change in the method of distribution at the present time, with the old practices so firmly fixed throughout the valley, would be a large undertaking and one which of necessity would have to come slowly. Such a change would require on the part of the farmers the formation of a large number of local water associations or organizations of some kind for the purpose of regulating the water and dividing it among themselves. Such organizations should be as simple as possible and at the same time be effective. The faculty of organization is not commonly found among farmers, and in this matter some suggestions and assistance would perhaps be needed and appreciated. The first thing necessary, however, in bringing about a reform of this kind is to demonstrate the advantages to be gained by it. This it seems could be accomplished in no better way than by inducing the water users on one or two of the more important laterals in each community to adopt rotation in the use of water. In undertaking this plan, getting organized, and started right farmers should be rendered every possible assistance by this Office and by the management of the canal company. With the value and practicability of this system of distribution fairly demonstrated in a few sections of an irrigated district, it is only reasonable to expect that other progressive irrigators would not be slow in the adoption of similar methods.

While we would recommend a change in the present methods of division from laterals, we believe that the system of measuring all diversions from the main canal and the keeping of careful records of the same should be continued as begun on the Sunnyside canal in 1904,

and that other canal companies would profit largely by adopting similar methods. The most serious difficulty to be encountered in most places in connection with the operation of a system of this kind will be to keep weirs in proper condition for reliable measurement. The deposit of silt in the channels above the weirs and also in the laterals below is the worst obstacle to contend with in the Sunnyside district. Above the weir it rapidly reduces the necessary contraction, and by filling up the lateral below, raises the water so as to destroy the required fall. This is a problem which could be solved, however, by cooperation between the farmers and canal companies, if the importance of maintaining such measurements were more fully appreciated by all parties interested, and need not stand as a permanent impediment to such a system of distribution.

PREPARING AND SEEDING NEW LAND FOR IRRIGATION.

In the Yakima Valley the greater portion of the land in its natural state is covered by a more or less heavy growth of sagebrush. The size and strength of this brush is usually a good indication of the character of the soil where it grows, the best soil in general producing the best sagebrush. Ordinarily the height is from 18 inches to 3½ feet, and the stalks or trunks seldom exceed 3 inches in diameter. Before land can be successfully plowed and put in shape for cultivation it is necessary to remove the brush. The methods of doing this work are quite similar throughout the valley, and considerable has been published in regard to the details and cost of clearing land, so it will not be discussed at length in this report.

With a growth such as is ordinarily found a man can grub about an acre in a day by working hard, and to gather up the brush and burn it requires possibly a half a day, so that the cost per acre with wages at $2.50 per day would be $3.75 by this method. This is a slow way of clearing land, however, and where laborers are usually hard to get, other means are more generally employed.

The commonest method is that of breaking the brush off by dragging a railroad rail or heavy timber over it, and then back in the opposite direction, using four horses for this purpose, a team on each end of the rail. This work can be done best when the ground is frozen, as it is easier to break the brush when the soil is hard. The cost of clearing in this way varies considerably with the character and density of the growth to be removed. At Prosser, Mr. J. T. Brownfield has had it done by contract at $2.50 per acre, including burning the brush. Mr. Charles Griffeth at Kennewick cleared 100 acres in the fall of 1906 at $3 per acre. At Ellensburg a different method has been employed for clearing brush. Here very heavy double gang plows were used, drawn by six large mules. The plows were set so as to go very deep and tear the brush out or cut off the roots. This work was

done by contract for $3 per acre, 5 acres per day being the average day's work, and it cost an additional $1.50 per acre to pick up and burn the brush. Walking plows and heavy single-riding plows were tried for this work, but could not be kept in the ground. Instead of picking up the brush by hand, it is a common thing to use a sort of rake which is drawn by a team.

After the sagebrush is removed the land can be plowed with any ordinary strong plow. Three horses are commonly used. This costs from $1.50 to $2 per acre. Two dollars was the contract price for plowing 100 acres of sandy land at Kennewick in 1906. Often considerable leveling is required also before a piece of land can be properly irrigated. This is the most particular part of the work and should be very carefully done, especially if alfalfa or a grass crop is to be sown. On account of the increased labor in irrigation and the decreased yield which usually results from not having a field properly leveled, it is poor economy to spare labor or expense on this part of the work of preparing the land. By leveling is not meant that the land shall actually be made level, but that it be given a fairly uniform slope and have all inequalities removed. As a rule the rolling land is the easier to prepare for irrigation, as the cost of leveling is commonly less. The buck scraper is the most important implement used for moving dirt, although a wide steel scraper known as the "Fresno" is used quite extensively also. For finishing the grading to even up the surface and fill small irregularities the planer or straight edge is used. This consists of two pieces of 2 by 8 inch material, from 16 to 20 feet long, which are turned up on edge and have other pieces of the same material, about 6 feet long, spiked between them so as to form a kind of float 6 feet wide and 16 to 20 feet long. It is drawn lengthwise the same as a sled, and is very effective in removing small hummocks that could not be detected by the eye. As a rule no instruments other than the spirit level are used in determining elevations for this business, but some form of cheap level with a tripod would be found very useful. We saw one man using a spirit level with a soap box as a substitute for a tripod. He did the work, but found it necessary to travel around on his knees much of the time. Very frequently no level instrument whatever is uesd. If water is available trial furrows are made when the leveling appears to be nearly enough completed, and if water will run through to the end it is good; if not, the work continues. It is considered a good practice to irrigate a field once before seed is sown if much leveling has been done or many depressions have been filled, as this causes the soil to settle in places, showing where further leveling is needed. If this were not done there would be low places in which water would stand, where the settling had occurred, and this would make it difficult to irrigate the field evenly.

The cost of leveling depends altogether upon the character of the land, some tracts requiring a great deal more work than others. However, from the most favorable conditions to the most unfavorable under which leveling is done, the cost ranges from about $5 to $25 per acre, with the average between $12 and $17.

There are some other items of expense necessary in preparing the land for irrigation, for frequently it costs something to get water to the land, and the construction of flumes or head ditches from which to distribute it always requires an expenditure more or less great, depending on how well the work is done. Head ditches with spouts made of lath are more extensively used than flumes in the upper and older settled parts of the valley, while in the Kennewick district scarcely anything but flumes are used. (Pl. II, fig. 1.) They are, in general, more satisfactory.

In regard to the total cost of preparing land a few specific instances will be included with the various expenses itemized. The following is a statement by R. K. Tiffany, formerly chief engineer of the Washington Irrigation Company, on the cost of improving land under the Sunnyside canal:

Cost per acre of preparing land for irrigation.

Clearing and burning brush	$5.00
Leveling, building head ditches, seeding, and watering first time	15.00
Seed—16 pounds of alfalfa, at 15 cents per pound	2.40
Three pecks of wheat, at 60 cents per bushel	.45
Lumber for head ditch, checks, and lath for spouts	2.00
Total	24.85

The wheat and alfalfa for the first year paid cost of irrigation—about $1.50 per acre.

The cost of building flumes, if irrigation is from flumes only, would be about $4 to $5 per acre for good, substantial flumes laid on the ground.

Head ditches, counting labor of building, checks, spouts, etc., would be somewhat cheaper—about $2 to $3.50 per acre—but they are more expensive to maintain and operate.

These figures are for rough, sandy soil, with a good slope. Flat, sandy land would cost more to level; smooth, rolling land would cost less.

The brush is what we would call heavy, the larger being 3 to 5 feet high and 3 to 6 inches through at the ground; probably 6 to 10 clumps to the square rod. The brush was first railed by dragging a 12-foot length of 60-pound railroad iron across and back over the same strip in opposite directions, thus forcing the brush both ways. This required four strong horses. As the soil was a rather sandy volcanic ash, this effectually loosened and pulled up three-fourths of

the brush. The loosened brush was then raked into windrows with a brush rake. The process left everything flattened and easy of attack with the grubbing hoe. This land was gently rolling, with some few wind-formed hummocks from 1 to 2 feet high around the sagebrush, which were almost entirely leveled by the railing. This land was carefully graded the first time and required no additional work after the first watering. It sloped so gently that the water did not wash or cut deep gullies. The soil is a light, sandy loam 60 feet deep, with occasional streaks of hardpan.

For clearing 40 acres in the Moxee district and planting to potatoes, Arthur Belliveau reported the following:

Cost of preparing land for irrigation and planting crop.

Grubbing, raking, and burning sagebrush, at $2.50 per acre	$100
Plowing, at $2 per acre	80
Four days' scraping with 2 teams and 2 men, at $6 per day	24
Leveling, 1 man and 2 teams, 8 days, at $5	40
Planting, 16 days, 3 men and 1 team, at $5	80
Seed, 17 tons, at $6 per ton	102
Ditching, 8 days, 1 man and 1 horse, at $2	16
Total	442
Average cost per acre	11.05

For a crop of this kind the land does not need to be so carefully graded as for alfalfa.

In the Kennewick district, where the soil is in most places very sandy and some conditions in other respects are somewhat different from those generally found in other sections of the valley, the irrigation practice is necessarily more or less modified. The methods of clearing and leveling are practically the same, but here the blowing of the sand is one of the peculiar problems which has to be taken into consideration. While the natural surface is undisturbed and covered with a strong growth of sagebrush, this does not occur to any considerable extent, but as soon as the brush is removed and the ground plowed the drifting is quite likely to begin. To prevent such drifting it is the general custom to sow rye upon the land as soon as the leveling is completed, or even just after it is plowed, if further improvement is to be delayed for any length of time. If sowed in the fall or very early in the spring, this will usually mature without being irrigated, or will at least make such a growth as to quite effectively prevent the blowing, and when plowed under serves to add to the soil humus, which naturally is lacking.

As there are yet thousands of acres of this land to be irrigated, some specific notes with reference to the cost of making improvements necessary for its cultivation and irrigation may be of value to parties interested in this district. Of course, costs will vary in accord-

ance with the conditions of individual tracts here as elsewhere, but the following statement will give some general information bearing on the subject under consideration. These notes were kindly supplied by Prof. George Severance, of the State College of Washington, and give the total expense incurred in putting 43 acres of this sandy land under cultivation near Finley, Wash., in the summer of 1906.

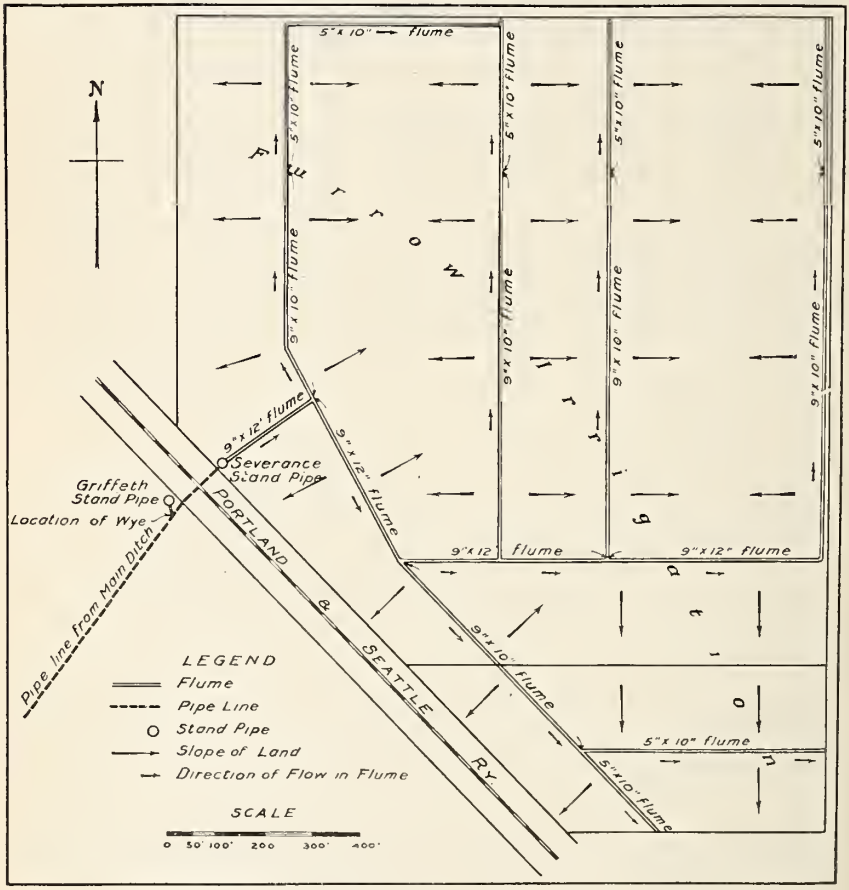

FIG. 1.—Plat of 43-acre alfalfa farm at Finley, Kennewick district, Washington.

The location of flumes and slope of land is shown in figure 1. The cost as given below includes the construction of a pipe line to conduct water from main canal to land, built to supply 100 acres, 43 acres belonging to George Severance and 57 acres to C. E. Griffeth; distance, 3,000 feet; fall, 20 feet; size of pipe, 8 inches, made of wood staves, machine banded.

Cost of preparing 43 acres for irrigation.

Pipe used to bring water to wye (where division was made), at 23 cents per foot	$695.40
Overseer for laying pipe, 11 days, at $3.50	38.50
39 days' common labor, at $2	78.00
3 days' common labor, at $2.25	6.75
2-horse team, 3 days, at $2	6.00
Man and 4-horse team, 1 day	6.00
Making drills	1.25
Powder and fuse	3.35
Total	835.25
0.43 of $835.25 (charged to the 43 acres)	359.16
One-half cost of 8-inch wye	8.75
124 feet of 8-inch pipe to carry water from wye across railroad to Severance standpipe, at 23 cents	28.52
Standpipe at flume	29.40
Total to bring water to land	425.83
2 men 1 day with surveyor's level taking data for map	5.00
Leveling 43 acres at $15 per acre	645.00
Total for mapping and leveling	650.00
Hauling 25,000 feet of lumber 6 miles, at $2.50 per thousand	62.50
14,570 feet 1 inch by 10 inches, at $17 per thousand	247.69
1,932 feet 1¼ by 12 inches, at $22 per thousand (cedar)	42.50
261 feet 1¼ by 8 inches, at $22 per thousand (cedar)	5.74
3,130 feet 1 inch by 6 inches, at $21 per thousand (cedar)	65.73
2,000 feet culls 2 by 4 inches, at $14 per thousand	28.00
32 feet 4 by 6 inches, at $18 (for marker)	.58
18 feet 3 by 4 inches, at $12 (for well)	.22
704 feet 1 inch by 12 inches (culls) at $15 per thousand	10.56
6 bundles cedar laths, at 45 cents	2.70
2 cords cedar blocks, at $5	10.00
175 cedar posts for supporting high fluming, at 10 cents	17.50
12 pounds tin disks for washers on cut-offs of small flumes, at 15 cents per pound	1.80
Nails	26.00
Total bill of material for fluming laid down on land	521.52
1 man 2 months, at $60 per month	120.00
100 days' extra labor, at $2	200.00
16 days with 2-horse team, at $2 (team used for drilling, furrowing land for irrigation, hauling flume boxes, etc., and distributing same over field)	32.00
1 month's time of owner	60.00
Use of drill for 43 acres, at 10 cents	4.30
Total labor account for setting up fluming, seeding land, and tending water	416.30
40 bushels rye, at $1.50 per bushel (for seed)	60.00

SUMMARY.

Getting water from ditch to land	$425.83
Mapping and leveling land	650.00
Material for fluming	521.52
Labor connected with fluming, seeding, and watering	416.30
Seed	60.00
Grand total	2,073.65
Cost per acre	48.22

Piping water over half a mile is a heavy expense which would not ordinarily be necessary. In putting in this line rock had to be blasted for 300 or 400 feet. Leveling was let by contract, the contractor averaging $7 per day for himself and four horses, with the going price at $6. A man understanding leveling could probably, by doing the work himself, have done it for $200 less than the contract price.

The 1 by 10 inch stuff is larger than would be necessary for the greater part of the fluming, but the lumber yard had an overstock of this size and put the price down to $17, with the price of commoner sizes at $21 for 1-inch material and $22 for 1¼-inch. Where the flumes were only 1½ to 2 feet from the ground, cedar posts were sawed in two and split, making four pieces from one 10-cent post. Two of these pieces were set in the ground at each joint of the flume, with a piece of 2 by 4 inch nailed across for the flume to rest upon. Where the flume lay broadside to the wind it was found necessary to put an occasional whole post deep in the ground on the lee side to prevent the wind from overturning it. Where the flume set close to the ground, cedar blocks were put under it. Two by 4 inch bracings were put under the center of each flume section. Sections with 12-inch bottoms were 16 feet long; all others 20 feet long. The cost of setting up the flumes is considered altogether too high, as it was done by a man working by the month, with the employer absent.

For fence, one 10-cent post every 20 feet is sufficient, and $15 worth of barbed wire will make three strands 80 rods; 5 cents per rod will put it up in this character of soil.

APPLICATION OF WATER TO CROPS.

It is practically the universal practice throughout the Yakima Valley to apply water to crops by some form of furrows, varying somewhat in distance apart, depth, and length, but in general involving the same principle, the intention being not to flood the surface of the ground but to allow the water to percolate or seep out from the furrows so as to wet the intervening spaces. These furrows are usually 3 or 4 feet apart when intended for the irrigation of meadow land, and about 4 to 6 inches deep. They are made with the marker or sled with the runners the proper distance apart and formed so as to

make the furrows about 4 to 6 inches wide and about the same depth. The front end of the runner is often fitted with small cultivator shovels. These same markers are sometimes used in cleaning the furrows in the old fields.

When seeding land, it is usual to make the furrows 18 inches to 2 feet apart, and after the grass is thoroughly rooted to abandon every other one. The furrows should run on gentle slopes. If given too steep a grade, the water will cut deep gullies into the soil. Not enough attention is given to this matter in many instances, especially in orchards on hillsides. With alfalfa land it does not make so much difference so far as washing is concerned, as the roots of the plants prevent it, but more waste of water results as a rule where it runs so fast.

Water is turned into the furrows from head ditches, usually through spouts 24 inches to 30 inches long, made by nailing four pieces of lath together. These are set in the bank of the head ditch, one for each furrow, and arranged so that the water can be shut off by placing a block over the upper end. Flumes are frequently used as a substitute for the earth head ditches, and have holes bored through the sides through which the water is supplied to the furrows. Pieces of lath are usually nailed to the flume so that they may be turned to cut off the flow of any opening, as desired. The flumes for this purpose are usually more satisfactory than the head ditches and are coming into general favor, being easier to regulate and more economical of water.

While the above methods are the most general, there are a few places where different ones are employed. In parts of the Ellensburg district where alfalfa and timothy are the principal crops, larger furrows are made across the meadows at distances of a rod or more apart, and then large heads of water turned in, which are allowed to run over and flood the ground. This system is also employed largely throughout the valley on most of the older farms which lie along the river bottoms, where the ground is more or less gravelly and has never been carefully leveled or prepared for other methods of watering. This is a wasteful and primitive method, however, a relic of the time when water was no object and labor was the thing economized.

The contour check system has been used for fifteen or twenty years in the irrigation of meadows on the Moxee farm, where much of the land is flat. Several hundred acres of land have been prepared in this way, the fields being watered by flooding the checks. As so much of the land of the Yakima Valley is rolling, this method can not be widely adopted, so some form of furrow irrigation will undoubtedly continue to be the general practice.

CROPS OF THE YAKIMA VALLEY.

In the Yakima Valley almost any crop can be grown that is known to the Temperate Zone, and many of the tenderer fruits, such as peaches, apricots, grapes, etc., which require the most favorable climatic conditions, are raised with entire success and develop to a state of perfection unexcelled anywhere. Even the English walnut may be grown with some success, and there are a number of places where trees have matured fair crops. As a natural outgrowth of the production of so great a variety of crops come other related industries, such as dairying, poultry raising, beekeeping, etc., which, although they take nothing directly from the soil, add immensely to the revenue from the farms.

Together with the ability to grow large and varied crops the markets are such as make their production unusually profitable. To the west, with Seattle, Tacoma, and other cities only a few hours distant from the center of the valley, together with Alaska and the Orient, there is a large and rapidly growing demand for the fruits, hay, and products of all kinds which the Yakima farmers have to sell; while to the east, Spokane, Helena, Butte, and the mining districts all over Montana, Idaho, and British Columbia have to look to Yakima Valley very largely for these same products, and even as far east as New York City, in a State famous for its apples, the Yakima Valley apples are selling for 5 cents each.

A few of the more important crops, with the methods of irrigation and culture, together with cost of productive yields, etc., are discussed in the following pages.

ALFALFA.

This is the most common crop grown in the Yakima Valley, being usually the first on new land, and seems to be very well adapted to conditions in all the different districts. Ordinarily in the sandy loam land it is an easy crop to start, does well on the virgin soil, and when plowed under after a few years leaves the soil enriched and in excellent condition for orchard or field crops.

The preparation of the land has already been described. Seeding may be done at any time during the season from the middle of April until late in the fall. It is not so easy, however, to get a good stand during the hottest part of the summer, on account of the difficulty in keeping the ground constantly moist. This is essential until the tender plants are well rooted. Again, it is not advisable to do much seeding as a rule after the 1st of October, for the water is beginning to get cold by this time, the seed does not germinate so quickly, and frosts are more liable to injure the young plants.

Sixteen to 18 pounds of seed is sown per acre, and it costs 15 cents per pound. Wheat or rye is often sowed with the alfalfa, especially if the ground is sandy and in danger of drifting. At Kennewick 45 to 50 pounds of rye per acre was sown in February on land which in April was also seeded to alfalfa. There was enough natural moisture in the ground to sprout the rye, which by the time the alfalfa came up was large enough to give some protection to it.

When the seeding is done early in the spring it may be possible under favorable circumstances to get during the first year two light cuttings, together yielding perhaps 1½ to 3 tons of hay. After the first year, three crops of hay are generally cut each season, and considerable fall pasturage is afforded, although the fourth crop is very frequently made into hay. This comes so late in the fall that usually it is difficult to properly cure it, and it pays better in most places to sell the pasture, which brings $1 to $2 per acre. The yield per acre in three cuttings runs from 5 to 9 tons, with 7 tons about a fair average.

Enormous quantities of alfalfa hay are baled each year and shipped out of the country, bringing $8 to $12 per ton on the cars. Another way in which it is disposed of is by feeding to thousands of sheep and cattle which are driven in off the ranges to be wintered or fattened. The hay is then measured in the stack and sold at from $4 to $6 per ton.

Irrigation practice in alfalfa growing varies somewhat, but commonly a field is well wetted during April and May before cutting the first crop, and again after the haying is over each time in order to produce the succeeding crop. Some irrigators wet the fields shortly before cutting as the grass starts quicker after the hay is taken off.

The cost of production and returns in a few instances which may be considered fairly typical are given below.

Mr. William McDonald, of Prosser, Wash., cut 145 tons from 18 acres in 1905. The first crop, cut June 12, made 60 tons; the second, cut July 24, 55 tons; and the third, cut September 7, yielded 20 tons. The cost of producing the crop, including water, was $177.70, or $1.23 per ton in the stack. It was sold for $5 per ton in the stack, giving a net profit of $547.30, or $30.40 per acre. The cost of labor for handling the three crops was distributed as follows: First crop $52.50; second crop $55.50; third crop $36.50. Water cost $1.50 per acre. This was an old field, and lack of water materially reduced the third crop. The land is valued at $150 per acre under existing conditions.

This same season reports of yields and returns from alfalfa crops grown on six other farms in different sections of the valley were also obtained. The results summarized are as follows:

From a total of 209.5 acres 1,577.7 tons of hay was produced, or at

the rate of about 7½ tons per acre. The average cost of production was $1.34 per ton in the stack, and the average net returns per acre were $24.60. The land on which these crops were grown is valued at from $150 to $300 per acre.

In getting the data, hay was measured in the stack, the following rule being used: To the "overthrow" or distance over the stack add its width at the base, divide by 4, square this result, and multiply by the length; divide this by 512, which gives the number of tons. The stack should stand thirty days before being measured. The general opinion is that this rule, which is called the "Government rule," gives results somewhat larger than the actual weight in most cases.

TIMOTHY AND CLOVER.

Timothy and clover are grown quite extensively also, being the principal hay crop in the Ellensburg district. These are grown together. Two cuttings only are made each season, the first being mainly timothy, and the second clover. Timothy is considered to be superior to alfalfa for hay, and brings several dollars more per ton. Nearly all of it grown is baled and shipped. It requires more water than alfalfa, and is generally not so well adapted to conditions found in the Yakima Valley.

POTATOES.

The potato is one of the important crops, being grown successfully almost anywhere in the Valley. The Moxee district and the Yakima Indian Reservation, however, are, perhaps, the most important potato growing sections, where a large acreage is devoted to this crop each year. Potatoes are frequently planted as the first crop on new land, and sometimes give fair returns, but by far the best yields are obtained on old ground, especially where alfalfa or other grass crop has preceded. The ground is plowed, harrowed, and frequently is also irrigated before planting. About 700 to 1,000 pounds of seed is used per acre, planting usually being done about the middle of May. The first irrigation after planting is given about the middle of June, and the last early in August. They do not require a large amount of water in the sandy loam soils commonly found. Seven to eight tons per acre is considered a good yield under ordinary conditions, although on old alfalfa or clover ground larger yields are commonly expected. Prices vary considerably from year to year, but $10 to $12 per ton is about an average price, taking one year with another. Some specific instances showing yields, costs of production, and returns in 1905 are given below.

Mr. Harry W. Fiske, of Prosser, reported a yield of 80 tons from 8 acres of typical sandy loam land, this being the second season in

potatoes. The returns at $13 per ton were $1,040. The cost of production including seed, water, and labor of putting on board cars was $321.50, leaving a net profit of $718.50, or nearly $90 per acre.

L. D. Humphrey, of North Yakima, reported a yield of 91.5 tons from 10 acres on alfalfa land. Of this crop, 81.5 tons graded as No. 1, 5 tons No. 2, and 5 tons small. The selling price was not stated, but at $10 per ton (a fair average price) the returns from the No. 1 grade would have been $914.76. The cost of production was $444.50. Not considering the value of the second-grade potatoes, this would leave a net profit of $470.26. The crop was irrigated twice in July. The labor of growing was itemized as follows:

Labor of raising crop of potatoes.

	Hours.
Plowing, 1 man and 3 horses	50
Harrowing, 1 man and 2 horses	15
Plowing, 1 man and 2 horses	50
Planting, 1 man and 2 horses	30
Cultivating, 1 man and 2 horses	60
Ditching for irrigation, 1 man and 1 horse	20
Hoeing	70
Hilling, 1 man and 1 horse	18
Irrigating	20
Digging, 1 man	700
Digging, 2 horses	48

Four fields, aggregating 27 acres, gave an average yield of 8.83 tons per acre, with total cost of production $5.90 per ton. The mean net returns per acre for the potatoes, based on current prices, deducting cost of producing and 75 cents per ton for placing on cars, were $61 per acre.

CORN.

A considerable amount of corn is grown in the North Yakima district and other sections farther down the valley; more under the Sunnyside canal, however, than elsewhere. It is a good crop, yields well, and brings good prices in the local markets, but is of no great commercial importance, as none is shipped out of the country. Deep plowing and deep planting are the customary practice in growing this crop. Some farmers irrigate the ground before planting. The seed is then placed about 6 to 8 inches deep, in rows 3 to 4 feet apart. The first cultivation is given when the corn is 6 or 8 inches high, and it is irrigated first early in June. Following this irrigation the ground is thoroughly cultivated so as to pulverize the surface and form a mulch which retains the moisture. When land is irrigated before planting, it is the usual practice to irrigate when the corn is in tassel and again at the time the ear is forming. The practice of irrigating

before planting, however, is not generally recommended unless the ground is very dry, as it makes the ground cold and retards germination of the seed. If the ground is not wet before the corn is planted, the first irrigation is usually given when it is about 2 feet high.

HOPS.

Hop growing in the Yakima Valley is confined almost entirely to the North Yakima district and lands under the Sunnyside canal, although there are some hops grown as far down as the Kennewick district. The hops are of good quality, and in general this is one of the best paying crops grown. Considerable money is required to set out a hop yard and put up the buildings necessary for curing and handling the crop, and for this reason they are grown by farmers having large land holdings. The yards seldom contain less than 20 acres, and from this they range to 100 acres or over.

The best yards are equipped with what is known as the "trellis system." The trellises cost from $75 to $90 per acre, but they last for twelve or fifteen years. The plants are placed in hills 4 to 6 feet apart each way, and are irrigated by furrows which run on each side of the rows, from 1 to 2 feet from the plants. Cultivation is one of the prime requisites in growing hops, as it is necessary to keep down the weeds and have the ground in the best possible condition. At least three cultivations are required, and many yards receive more. There is no definite rule for irrigating, but usually three times during the season is sufficient, the first water being needed about the middle of May or first of June. Again at the time the burr forms there should be plenty of moisture. Late irrigation retards the ripening, and sometimes in large yards the hops which are to be picked last will be irrigated later than the others in order to keep them green until about ready to be taken off.

From 1,500 to 2,000 pounds to the acre are the usual yields on yards which are in good condition. The cost of production is 7 to 9 cents per pound, not including the cost of trellis work or poles. Where the yards are established, it is common to have the hops grown by contract for 8 or 9 cents, this to include all labor of cultivation, irrigation, picking, curing, and baling ready for the market, together with furnishing the necessary twine for stringing the yards. The selling prices range from 8½ cents up, and in 1904 hops sold for over 30 cents per pound. With the cost of production less than 10 cents and a market price over 30 cents, some modest fortunes were made from the large yards in the one year.

The following is a statement of the labor and cost of operating W. H. Dimmick's yard at North Yakima, in 1905.

Cost of operating hopyard, 1905.

Hours.	Kind of labor.	Cost.
240	Man cleaning yard	$48.00
110	Man and team plowing yard	38.50
30	Man and horse harrowing	8.25
20	Two men repegging yard	8.00
60	Six men and one team twining	81.00
70	Man and one horse cultivating	19.25
40	Eight persons training vines (principally women)	36.00
80	One man irrigating	16.00
25	Five men cutting back before training	25.00
50	Ten persons suckering	55.00
70	One man and horse cultivating	19.25
50	Eight persons training	45.00
60	Ten persons suckering	66.00
80	Man and horse cultivating	22.00
40	Man and horse ditching for irrigation	11.00
70	Two men cutting weeds	28.00
160	Four men tying up hops which had fallen down	65.00
	75 pickers, 23 days, 2,579 boxes, at $1 per box	2,579.00
	Drying, baling, and hauling	925.00
		4,094.25
	Sacks, and use of boxes for year	30.00
	Twine	216.00
	Water	15.00
	Total	4,355.25

The owner reported a yield of 60,300 pounds from this 20-acre yard in 1905. The cost of production, including water, was about 7.3 cents per pound. The crop was sold for 8½ cents per pound, bringing $5,125.50, and netting $767.50, or a little more than $38 per acre. A price of 10½ cents per pound was refused at one time, and if the crop had been sold at this price, which is a very low one, the net returns would have been over $98 per acre.

In 1904 Mr. R. D. Herod sold 36,800 pounds from a 14-acre yard, at 29½ cents per pound, thereby realizing a net profit of over $560 per acre. Such a price, however, is unusual. In the spring of 1906 many growers contracted their crops in advance for 10 cents per pound, the price about November going to about 17 cents. These yards in 1905 were valued at from $250 to $400 per acre.

ORCHARDS.

Orchards are grown more or less extensively throughout the valley, but at present the North Yakima district and the lands constituting the western or upper part of the Sunnyside district are preeminently the orchard sections. This is due largely to the fact that these are older-settled communities. All through the valley old meadow lands are now being plowed up and converted into orchards. The change is coming partially from better shipping facilities, the dividing up of large farms, and from the improved financial condition of the farmers in general, who in the beginning could not afford to plant orchards and wait several years for the first returns, so started in by growing alfalfa or other hay crops.

Apples, peaches, and pears are the three fruits of greatest commercial importance. Of these, apples, and especially the winter varieties, easily lead. The best practice in planting is to place the trees about 30 feet apart each way, by what is called the triangle system. In many of the older orchards they are only 20 to 25 feet apart, but experience has shown this to be too close for apple trees, although about right for pears. Very often, with the apple trees 30 feet apart, peaches will be set between them, and as they mature much quicker than the apple, several crops may be obtained before the apple trees are large enough to bear, and the peach trees may then be taken out. Potatoes, corn, or other crops are grown between the trees when they are small, in order to get some revenue from the land while the orchard is growing. A crop should be selected which requires about the same amount of water as the trees, for when strawberries, for instance, which require much more water, are planted between the rows, the growth of the trees will be retarded in a very marked degree.

The orchards are irrigated entirely by the furrow system, although there is more or less variation as to time of watering and as to the quantity applied. Where they are planted on deep loamy soil, three irrigations are usually considered sufficient if thorough cultivation follows each, but if the trees are in such shape that the ground can not be well tilled, more frequent wetting is necessary. On the deep soils it is commonly not necessary to irrigate until early in June. The next application is made about the middle of July, and the last near the middle of August. Where the soil is gravelly or has a gravel subsoil the irrigation begins about the first of April and continues till the middle of September. Some orchardists make the irrigation furrows on each side of the trees 4 to 6 feet distant from them and allow the water to run in each furrow for a couple of days, or until the ground appears to be sufficiently moist, when it is turned into other furrows. This is perhaps the most common practice. Cultivation is considered to be of very great importance, and all the best orchards are kept perfectly free from weeds, with the soil at all times worked so as to have a deep mulch over the surface, which conserves the moisture.

With few exceptions, the orchards are small, ranging from 5 to 20 acres. The labor, however, required to properly care for 10 acres of bearing orchard is greater than that of a much larger farm with ordinary crops, but the returns are large in proportion. The following are a few examples showing cost of production and profits from the large fruits:

Mr. E. Shenaur, of Zillah, Wash., reported the yield and returns from 40 Bartlett pear trees and 200 Spitzenburg apple trees as follows: Apples, 808 boxes, at $1.80 per box; 150 boxes culls, at 40 cents per box; total, $1,514.40. Cost of production was $442.64, leaving a net profit of $1,071.76. or $5.36 per tree, or $428 per acre. The trees were 12 years old.

The pears yielded 240 boxes, which sold for $1.25 per box, bringing $300. The cost of production was $76.40, leaving net returns of $223.60, about $5.60 per tree, or $447 per acre. These trees were also 12 years old.

Mr. S. F. Walden, of Zillah, reported a yield of 304 boxes from 41 Rome Beauty apple trees 11 years old. They sold for $1.65 per box, bringing $501.60. The cost of production was $138, which leaves a net profit of $363.60, nearly $9 per tree, or at the rate of over $700 per acre.

Mr. W. L. Wright, of North Yakima, has 18 acres of orchard. The apple trees are 30 feet apart and some of the orchard is filled in with peaches, pears, and apricots between the apple trees. After having top-grafted about 200 of the apple trees in the spring of 1906, which reduced the yield, the owner reported the following for the orchard: Apples, 4,000 boxes, $3,500; peaches, 2,000 boxes, $1,000; pears, 500 boxes, $500; cherries, $65; apricots, $20; prunes, $50, making a total of $5,135. The cost of production was about $1,500, which leaves a net balance of about $200 per acre for the entire orchard. The trees were mostly 11 years old.

The Spitzenburgs and Rome Beauties are fancy varieties which always command more than the average price, but the net returns per acre, taking the orchards as they are found, with all the different kinds of fruit represented, are from $200 to $600 each year, and orchards in bearing are valued at from $500 to $1,200 per acre.

STRAWBERRIES.

Of the small fruits grown in the Yakima Valley strawberries are of greater commercial importance than any of the others at present. They are raised throughout the entire length of the valley from Ellensburg to Kennewick, but as the season is so much earlier at the latter point it is here that they are grown with greatest profit and the most attention is given to their culture. It is the common practice in this district to plant them between the rows in young orchards and in this way get some returns from the land while the trees are growing. The cost of putting out strawberries is about $40 per acre after the land is prepared. Eight thousand to 10,000 plants are required, costing from $2.50 to $4 per thousand. They are set in rows 3½ to 4 feet apart and 12 to 18 inches apart in the rows. The first irrigation is given them early in April and then as often as they seem to require it up to the picking season, during which time they are irrigated at least every other day and sometimes daily. After the crop is taken off they get only enough water to keep the plants alive.

The returns from strawberries depend almost entirely upon the time they are put upon the market, the largest profits coming from the earliest berries. The first shipments are made from Kennewick

the last of April and the last about the first of June. The following are a few of the yields reported in 1905 from the Kennewick district:

Mr. H. Delepine picked 210 crates from 2 acres, which sold for an average price of $4.45 per crate, bringing $935, or $467.50 per acre. The first ones were sold April 29, and the last picking was done June 6. The total cost of production, including water, plants, labor, etc., was $291.70, which left a net profit of $643.30, or $321.65 per acre. The land was valued at that time at $600 per acre.

Mr. H. M. Bartlett took 480 crates from 5½ acres, or 87 crates per acre. This crop was injured by frost and found a later market. The price was $1.62 per crate, which made a total of $777.60. The total expense of production was $421.50, which left a net profit of $356.10, or $64.75 per acre.

Mrs. M. E. Staley reported a yield of 400 crates from 3½ acres, or 115 crates per acre. The average selling price was $2.14 per crate, making the gross receipts $856. The cost of production was $329.50, which left the net returns $526.50, or $150.43 per acre.

COST OF WATER.

Under the cooperative canals the cost of maintenance and operation is covered by assessments upon the stock, and as the yearly expense depends largely upon the extent of repairs needed the assessments vary more or less from year to year, but under the canals where water rights are sold and definite maintenance fees stipulated in the contracts, the cost of water per acre is the same each year.

The following table is intended to show the annual cost per acre of water under the typical and more important canals of the valley. In making this table we have assumed an interest rate of 6 per cent on the cost of the water right or, in case of cooperative companies, interest on the approximate cost per acre which was expended in the construction of the canal. In cases of the latter kind the figures are also only approximate.

Annual cost per acre for water under typical canals.

Canal.	Contract amount per acre.	Cost of water right per acre.	Annual fee per acre.	Total cost of water per year.
Selah Valley	One one-hundred-and-sixtieth cubic foot per second.	[a] $30.00	$1.50	$3.30
Sunnyside	do.[b]	[c] 30.00	1.00	2.80
Kennewick	do	50.00, 75.00	1.00, 1.50	4.00–6.00
Kiona	do	[a] 30.00	1.50	3.30
Yakima Valley[d]	1 share	[e] 25.00	[f] 2.00	3.50
Selah-Moxee[d]	do	35.00	[f] 2.00	4.10
Prosser	One one-hundred-and-sixtieth cubic foot per second.	75.00	1.50	6.00
Benton Water Co	do	25.00	1.00	2.50

[a] Estimated.
[b] The Government offers new contracts to farmers who join the Sunnyside Water Users' Association. The new contracts allow 1 cubic foot per second for 120 acres. In payment for new contracts a credit of four-fifths the amount is allowed for the old contracts.
[c] Late contracts.
[d] Stock companies.
[e] Based upon approximate cost per acre for original construction.
[f] At present.

The cost of water under the old low-line canals, where no flumes are required, is usually much less than the above figures.

DUTY OF WATER.

Studies for the purpose of determining the duty of water in the Yakima Valley should be of the most vital interest to everyone who is in any way connected with irrigation work in this part of the State or who is in anyway concerned with reference to the future development and welfare of the valley. There are thousands of acres of fertile land now lying idle and worthless which, if water were available for its irrigation, would be among the most valuable in the State of Washington. The water, however, is limited, and the extent to which these land resources may be developed will depend almost entirely upon the degree of economy with which the supply is used.

The desire to attain the fullest development of these lands to make homes for thousands of families, and in this way increase the wealth and promote the best interests of the State, should in itself be reason sufficient for careful use of that upon which so much depends; but this is not the only argument for a high duty of water. The farmers in nearly every part of the Yakima Valley to-day are learning by bitter experience that if they are to preserve in a habitable condition the farms which have already been improved and the homes which they have established it will be by virtue of a more economical use of water than has been customary. The question in the future should be—not how much water can we get, but how much can we get along without and still produce profitable crops.

Some day, also, the question of rights of the various water users throughout the valley will come up for adjudication, and to properly and equitably carry out this work a further knowledge of the duty of water than now exists will be eminently essential, and the sooner such knowledge is obtained the better it will be for all concerned.

Information regarding the amount of water needed for growing certain crops under conditions as found in the Yakima Valley would also undoubtedly be of considerable value to engineers or others engaged in the design or construction of irrigation works in other parts of the State where development of this kind is only beginning. Under some of these new projects the water contracts of the companies specify amounts ranging from a cubic foot per second for 160 acres to 1 cubic foot per second for 360 acres, with various limits as to periods of delivery. In cases of this kind it might be of interest to investors to know something of the duty in some other part of the State in order to be able to make comparisons.

Questions with reference to this matter are continually being asked, and with only the present knowledge upon which to base estimates such questions are often very difficult to answer satisfactorily, and

one is almost invariably forced to reply that so much depends upon various conditions associated with the growth of a crop and the manner in which the water is applied that no hard and fixed rule can be laid down as to just how much shall be supplied in particular cases. These influencing conditions might be enumerated almost without end, but of course some have a more important bearing upon it than others.

The character of the soil and subsoil are two of the most important factors affecting the duty. Where a deep loam is underlaid by clay or other more or less impervious formation, the amount of water needed will be very much less than is required upon the same kind of soil having a gravel subsoil, and where the soil itself is sandy with gravel underlying, as in some parts of the valley, even more water is required. Again, in localities where the subsoil is very deep and retentive a great deal more water will be required during the first few years of cultivation than will be needed later, as this subsoil, which at the beginning is usually almost devoid of any moisture, will absorb an enormous amount. The largest part of the land now under cultivation in the Yakima Valley, especially under the high line canals, is the sandy loam with such deep subsoil, that a comparatively high duty should be obtained. These lands, however, are as a rule more or less undulating, which tends to require more water than is needed on the flatter portions where other conditions are similar. To offset this requirement, however, these higher rolling lands are the better adapted for orchards, which do not need so much as the grass crops commonly grown on the flatter and lower sections.

The care with which the land is prepared for irrigation and methods of applying water also bear directly upon the duty obtained. In the Yakima Valley, where the furrow system is used, the length of the furrows is a matter to which not enough consideration has been given, and the farmer who attempts to run the water 80 rods will, under otherwise similar conditions, get a very much lower duty than his neighbor who makes his furrows only half as long. Eighty rods is not an infrequent length in alfalfa fields, but better results with less water would be obtained if 20 rods were the limit, and in some places where the soil is sandy, with underlying gravel, this is too far apart for head ditches, and it would be wiser to make the furrows only about 250 feet long.

Climatic conditions and the length of the irrigation season also affect the duty of water. In the Yakima Valley the period during which water is applied to the land is about two hundred days. This is a comparatively long season, and with very little rainfall and high temperatures prevailing the evaporation losses from the surface of irrigated fields is something enormous, and any methods of application or cultivation which would effectually reduce such losses would

result in a much higher duty for the water. In 1901 the evaporation from a water surface at Zillah from June 1 to September 7 was 23.65 inches, which was a mean of 1.67 inches per week, and at Prosser it was about the same.

Poorly constructed or ill-kept canals and laterals also have much to do with what may be accomplished with water, and in the Yakima Valley the low general duty under many of the irrigation systems is due largely to the losses which occur in getting the water from the river to the land. On account of this condition, it is necessary to take from the river or from the canals, as the case may be, a great deal more water than would be required otherwise. This excess water sinks away into the earth and disappears, or, percolating down through underground passages, finally reaches the lower lands or bottoms bordering the river and here accumulates to form swamps and alkali wastes. The statement is often made that this water lost from the canals or wasted by careless irrigation in the upper parts of the valley finds its way back to the river to be used farther down, and that in this way such low lands and gravel bars act as reservoirs. We do not concur in this belief. The subsoil and bottom lands have a capacity for an immense amount of water, and the filling process begins with irrigation in the spring and continues throughout the entire summer. Some water, of course, seeps back to the river during this period, but the fact that such lands get wetter and wetter as the season advances is proof that more enters than escapes, and it is only in the fall after irrigation has been stopped for some time, and the water is no longer needed, that it begins to disappear from these saturated areas. So their ability to hold back water is an injury to the lands down the river, as well as a menace to the health of communities adjacent.

To increase the duty of water and improve conditions in general, such wastes of all kinds should be stopped. If the canal companies and irrigators themselves can not appreciate what these losses mean fully enough to initiate corrective measures, there should be some way to compel a more rigid economy. Under a few of the canals a certain amount of saving would be brought about if the irrigators were given only the quantities of water their contracts call for, but as most of the canal systems are cooperative, there is no way of compelling economy in the distribution and use, or in the amounts which they take from the river, so long as their rights are not exceeded. This being the situation at present, it is easier to take from the river twice what the land needs and waste half in transit than to improve the condition of the canals and laterals. This is one obstacle in the way of development in the Yakima Valley which should be removed by legislation.

In the past six years some investigations have been carried on in this part of the State to determine the quantity of water applied to

land under the various canals, but it might be said that nothing has, as yet, been done by which the actual requirements of crops can be told, for certainly no one familiar with agriculture would say that the amounts used were necessary for growing crops.

To determine the general duty under the canals, measurements were made with the current meter, usually near the heads of such canals, at various times during the season when different depths of water were being carried; in this way rating curves were made, and by keeping daily records of gauge heights the discharges were computed for each day throughout the season. In measuring the water applied to fields, weirs were usually placed in the supply ditches where they entered the tract under investigation.

DUTY OF WATER UNDER SUNNYSIDE CANAL.

Records of the Sunnyside canal have been kept since 1898, and the following table shows the mean monthly discharges, acreage watered, and depth of water applied from that date to 1906, inclusive, except 1903 and 1905. It may be noted that the depth applied has gradually decreased in eight years from 11.4 feet to 6.5 feet. This is due partially to more economical use, and in part to the fact that newly irrigated land requires a greater amount of water than old fields.

Water used under Sunnyside canal.

Month.	1898.	1899.	1900.	1901.	1902.	1904.	1906.
April.....acre-feet..	5,587	6,000	10,788	7,184	9,981	[a] 14,760	19,682
May.....do....	8,763	11,885	14,390	18,521	18,495	32,530	35,826
June.....do....	10,691	13,654	16,110	20,692	27,410	33,380	31,478
July.....do....	15,187	15,548	21,814	29,002	29,014	[b] 30,170	40,984
August.....do....	18,254	19,385	22,532	33,120	40,244	37,510	30,196
September.....do....	10,895	13,841	15,388	19,133	29,878	31,180	25,868
October.....do....	8,957	10,059	11,013	16,306	16,921	[c] 13,570	25,188
Total.....do....	78,334	90,372	112,035	143,958	171,943	193,100	209,222
Acres irrigated.....	6,883	8,497	10,947	14,964	18,870	32,000	32,000
Depth of water applied...feet..	11.4	10.6	10.2	9.6	9.1	6.0	6.5

[a] Period April 1 to 30. [b] Period 26 days. [c] Period October 1 to 15.

The distribution of the crops under this canal is shown in a general way by the following table:

Crops irrigated under Sunnyside canal, 1901.

	Acres.
Alfalfa	7,621.7
Timothy and clover	2,867.2
Orchard	2,179.3
Corn	527.5
Potatoes	505.4
Garden	282.1
Hops	382.1
Miscellaneous	598.7
Total	14,964.0

DUTY OF WATER ON R. D. DUNN'S HOPYARD, 1901.

This yard, containing 38 acres, is situated in Parker Bottom under the Sunnyside canal. The soil is a deep sandy loam. On this yard during the season, 130.49 acre-feet of water was used, distributed by months as follows: In May, 33.15 acre-feet; June, 20.75 acre-feet; July, 46.51 acre-feet; August, 30.08 acre-feet; depth of water applied during the season, 3.43 feet.

This was estimated as twice the amount used on the same field the previous year, while the yield fell 1,500 pounds short of the 1900 crop. There was some waste from this field, however, which was not measured, so the entire amount applied should not be charged to the hops.

This same yard was reported in 1902, with 12 acres of new land, making in all 50 acres. The crop was injured this year by the use of too much water in irrigation, followed by rain and cool weather. The old yard yielded 27,800 pounds, or 732 pounds per acre, which was less than half the yield for 1901. The young yard produced only about 2,100 pounds. This year's crop, however, was sold for the exceptionally high price of 26 cents per pound.

The following table shows water used:

Water used on R. D. Dunn's hopyard, 1902.

Month.	Water used.	Depth of water.	Rainfall.	Total depth of water received by land.	Month.	Water used.	Depth of water.	Rainfall.	Total depth of water received by land.
	Acre-feet.	*Foot.*	*Foot.*	*Foot.*		*Acre-feet.*	*Feet.*	*Foot.*	*Feet.*
April	00.00	0.00	0.13	0.13	September	00.00	0.00	0.02	0.02
May	16.34	.33	.07	.40	October	.00	.00	.06	.06
June	32.95	.66	.01	.67					
July	36.80	.74	.01	.75	Total	104.79	2.10	.30	2.40
August	18.70	.37	.00	.37					

DUTY OF WATER ON R. D. YOUNG'S FARM, 1901.

This farm is on a ridge about three quarters of a mile south of Sunnyside, and receives water from the Snipes Mountain lateral through an 8-inch pipe which discharges 0.95 cubic foot per second. During the season all of this water was used on 38 acres of land, with the following crops: Young trees, 18 acres; alfalfa, 17 acres; clover, 2 acres; lawn, 1 acre. The alfalfa yielded 125 tons and clover 10 tons.

During the last half of June, all of July and August, and half of September nearly all the water was required upon the alfalfa and clover. This equaled a depth of 10.6 feet over the 38 acres.

DUTY OF WATER ON ALFALFA AND ORCHARD AT SUNNYSIDE, 1902.

The following table shows the water applied to an 80-acre farm near Sunnyside. Of this area 54 acres yielded 452 tons of alfalfa; 26 acres

of orchard yielded 2,200 boxes of apples, 210 boxes of pears, and 10 tons of prunes. The water was measured by a Cipolletti weir, the depths being recorded daily by the ditch rider. Owing to imperfect lower contraction of weir due to accumulation of silt, the discharges toward the end of the season were probably somewhat larger than recorded.

Water used on alfalfa and orchard, Sunnyside, 1902.

Month.	Estimate of water used.	Depth of water applied.	Rainfall.	Total depth of water received by land.	Month.	Estimate of water used.	Depth of water applied.	Rainfall.	Total depth of water received by land.
	Acre-feet.	*Foot.*	*Foot.*	*Foot.*		*Acre-feet.*	*Feet.*	*Foot.*	*Feet.*
April	0.00	0.00	0.13	0.13	September	50.72	0.63	0.02	0.65
May	9.84	.12	.07	.19	October	24.63	.30	.06	.36
June	26.77	.35	.01	.36					
July	51.57	.64	.01	.65	Total	218.48	2.73	.30	3.03
August	54.95	.69	.00	.69					

DUTY OF WATER UNDER LATERALS OF THE SUNNYSIDE CANAL IN 1905.

Cipolletti weirs were maintained at the heads of the following laterals during the season of 1905, and records were kept by the ditch riders, the readings being made daily. Owing to difficulty in keeping silt cleaned out of the channels, the discharges are probably larger than those recorded.

The soils found under this canal are described in Bulletin No. 17, United States Department of Agriculture, Bureau of Soils.

Lateral No. 39.1 waters 437 acres of grass land and 59 acres of potatoes, corn, orchard, and miscellaneous crops, a total of 496 acres. The soil is Sunnyside sand, and the land is quite level.

Lateral No. 34.1 waters 1,335 acres, principally in alfalfa. This land is quite level and is affected to a considerable extent by subirrigation, which accounts for the small amount of water applied.

Lateral No. 32.3 waters 1,150 acres, of which 938 is in hay, 34 in orchard, and 178 in miscellaneous crops. The soil is mostly a sandy loam, but there is some Sunnyside sand, affected more or less by subirrigation in low places.

Lateral No. 29.1 waters 29.15 acres of hay, 7 acres of corn, 15.5 acres of potatoes, 5.5 acres of wheat, and 13.5 acres of orchard, a total of 333 acres. The soil is a deep, well-drained loam.

Lateral No. 19.6 waters 275 acres, distributed as follows: Hay, 156 acres; orchard, 84.5 acres; wheat, 2 acres; melons, 4.5 acres; corn, 2 acres; potatoes, 26 acres. The land is a sandy loam, well drained and rolling, some irrigated hillsides being quite steep.

Lateral No. 20.4 waters 198 acres, in alfalfa and orchard. The land is rolling and well drained, the soil being a deep sandy loam.

Lateral No. 27.1 waters 547 acres, principally in grasses. The soil is a well-drained, sandy loam.

The water used under these laterals is shown in the following table:

Water used under laterals of the Sunnyside canal, 1905.

Month.	Lateral 39.1.		Lateral 34.1.		Lateral 32.3.		Lateral 29.1.	
	Quantity.	Depth.	Quantity.	Depth.	Quantity.	Depth.	Quantity.	Depth.
	Acre-ft.	*Feet.*	*Acre-ft.*	*Feet.*	*Acre-ft.*	*Feet.*	*Acre-ft.*	*Feet.*
May	362	0.73	570	0.43	813	0.71	318	0.95
June	266	.54	380	.29	721	.63	167	.50
July	380	.76	603	.45	940	.82	294	.88
August	358	.72	600	.45	956	.83	272	.82
September	275	.55	315	.23	573	.50	104	.31
Total	1,641	3.30	2,468	1.85	4,003	3.49	1,155	3.46

Month.	Lateral 20.4.		Lateral 19.6.		Lateral 27.1.	
	Quantity.	Depth.	Quantity.	Depth.	Quantity.	Depth.
	Acre-ft.	*Feet.*	*Acre-ft.*	*Feet.*	*Acre-ft.*	*Feet.*
May	214	1.08	301	1.09	500	0.91
June	163	.82	190	.69	393	.72
July	231	1.16	273	1.00	535	.97
August	212	1.07	200	.73	301	.55
September	106	.53	178	.65	381	.70
Total	926	4.66	1,142	4.16	2,110	3.85

The quantities of water shown to have been applied to the lands under the above laterals are not the entire amounts used during the season, but during five months only. Some irrigating was done in April and a very little in places after the first of October, but complete records were obtained for the five months only.

The results show that the 4,334 acres received, during the five months, an average depth of 3.11 feet. This we would consider less than a fair estimate of the duty on all lands under the canal, as the quantities used under one or two laterals where subirrigation occurred brought down the general average. More water was used by laterals which supplied the rolling or hilly lands, but this difference no doubt was partially due as much to the above-mentioned cause as to difference in surface conditions.

DUTY OF WATER AT PROSSER.

For the Prosser canal, the water is pumped as described elsewhere in this report (p. 32). In 1901 the flume at the upper end of the west branch of the canal was rated, and a register recorded the fluctuations throughout the season. The results of the work are given below. This branch of the canal supplied at this time water for trees and lawns in the town of Prosser in addition to adjoining farms. The soil is the typical sandy loam as found in other parts of the valley, but this is underlaid at varying depths of a few feet by gravel, which affords subdrainage. The area irrigated in 1901 was 885 acres

and in 1902, 998 acres. The water used on these lands in the two seasons is shown in the following table:

Water used under west branch of Prosser canal, 1901 and 1902.

Month.	1901.		1902.	
	Quantity.	Depth.	Quantity.	Depth.
	Acre-feet.	*Feet.*	*Acre-feet.*	*Feet.*
April (7–30)	414.25	0.47	.....	.....
May	473.94	.53	115.65	0.12
June	455.39	.51	476.54	.48
July	475.95	.54	503.43	.50
August	481.85	.54	560.12	.56
September	487.24	.55	361.39	.36
October	432.39	.49	401.82	.40
Total	3,221.01	3.63	2,418.95	2.42
Rainfall	.....	.14	.....	.38
Total water received by land	.....	3.77	.....	2.80

The total estimated discharge of the pumps for the covered period in 1901 was 5,641.3 acre-feet. Deducting from this the discharge of the west branch, as given above, left 2,420.3 acre-feet, which was applied to 316 acres under the east branch. This showed for this land a depth of 7.66 feet, and with rainfall added, 7.80 feet. The land under the east branch is very gravelly in places and consequently requires more water than that west of town, but it is probable that the estimated discharge of the pumps was also above their actual delivery.

WATER USED ON THE FARM OF MAURICE EVANS, 1901.

The crops raised on this farm were: Alfalfa, 25 acres; potatoes, 1.25 acres; turnips, 1.25 acres; miscellaneous, 3.5 acres; a total of 31 acres. During the period extending from April 1 to November 1 this land received 111.16 acre-feet of water, or a depth of 3.58 feet.

The water for this farm was measured by a 12-inch Cipolletti weir, the readings being taken each day. The discharge from April 1 to 11, before the measurements began, was estimated. Mr. Evans reported a yield of 250 tons of alfalfa, about 8 tons of potatoes, and 100 sacks of turnips.

DUTY OF WATER ON MR. JORDAN'S FARM, 1901.

Mr. Jordan's farm consists of 20 acres, which was cropped as follows in 1901: Alfalfa 6 acres, yielding 50 tons; orchard 12 acres, yielding 5,000 boxes of winter apples; garden and yard 2 acres, yielding $500 worth of fruits. The measurement of the water for this farm was made by a weir in the supply ditch where it entered the tract, and the

depths were recorded by an automatic register. The water used is shown in the following table:

Water used on Jordan farm, 1901.

Month.	Water applied.	Depth applied.
	Acre-feet.	*Feet.*
May	15.4	0.77
June	30.59	1.53
July	35.33	1.76
August	33.31	1.66
September (1-15)	5.92	.29
Total	120.55	6.01

DUTY OF WATER UNDER THE SELAH-MOXEE CANAL, 1906.

As was explained elsewhere in this report, the Selah-Moxee canal supplies a few hundred acres of land in what is known as Selah Valley, and then after passing by means of a long flume around the point of Selah Ridge enters the Moxee district, where an area of about 4,340 acres is irrigated by it. In 1906 a rating station was established about a mile and a half below where the canal comes into the Moxee Valley, and during the season measurements were made at seven different times. A gauge rod was placed in the canal at this place, and a record of fluctuations kept from the time water was turned into the canal, May 3, until it was turned out, October 30. The flow during this period was very regular, with but slight variations from day to day, and the channel where ratings were made remained permanent and in good condition. Vegetation in the canal both above and below the rating station, however, reduced the discharge toward the end of the summer.

The soil under this canal is classified as a sandy loam, but is finer than that found in most other parts of the valley and does not seem to absorb water quite so readily. This soil in places extends to a considerable depth, but is usually underlaid at varying distances by hardpan. The land is nearly all rolling, with very good surface drainage.

The alfalfa is the principal crop, but there are also large areas of potatoes, hops, and young orchard. The total area is approximately 4,340 acres.

In Selah Valley, from the first few miles of the canal approximately 620 acres of land was watered during the season, principally alfalfa, with some potatoes and gardens. This land receives free water in return for old water rights. Altogether there is supposed to be about 1,200 acres under the canal in this district, and to supply this land an allowance of 18 cubic feet per second has been made. Of the 620 acres irrigated in 1906, about 410 acres is gravelly bottom land or is underlaid by gravel at a comparatively slight depth, while the remain-

der, on a higher bench, is deep sandy loam land with an even surface and quite level. The bottom land, as is generally the case all along the river, is not well prepared for irrigation, and in order to make some comparison between the amounts required on the two classes of land some measurements were made also at the upper end of the canal in Selah Valley. As water was wasted to some extent all through the early part of the season at the flume between the two districts, it was possible to get accurate estimates of that used in Selah Valley for only a short period. This estimate was made by deducting the amount received by the lower or Moxee district from the discharge near the intake. Measurements were made at the regular rating station established by the Reclamation Service.

The results of measurements for the two valleys are given below:

Water used under Selah-Moxee canal in Moxee and Selah districts, 1906.

Month.	Moxee Valley.			Selah Valley.	
	Mean discharge.	Depth applied.	Rainfall.	Water applied.	Depth applied.
	Acre-feet.	*Feet.*	*Inches.*	*Acre-feet.*	*Feet.*
May (3–31)	2,248.8	0.52	1.11	.....	.....
June	2,970.0	.68	.69	.....	.....
July	3,130.0	.72	.08	416.2	0.67
August	3,160.0	.73	Trace.	890.0	1.43
September	2,186.0	.50	.24	.....	.....
October (1–30)	1,418.0	.33	.12	.....	.....
Total	15,112.8	3.48	2.24	1,306.2	2.10

Measurements showed that seepage from the canal below the rating station was practically nothing, so the above amounts of water were actually delivered to the land or into the laterals in the Moxee Valley.

For the Selah Valley, deducting 5 per cent for loss between the two districts leaves a depth of 2 feet. The depth applied in Moxee district during the same period was 1.15 feet. The duty in Selah Valley for this period approximated 1 second-foot for 47 acres; on the Moxee district for the same period, 85 acres, and in the Moxee district for six months, 104 acres.

DUTY OF WATER UNDER KENNEWICK CANAL, 1906.

Under the first 20 miles of Kennewick canal very little land is irrigated and as considerable water is spilled back into the river at the upper end of flume No. 1 during the early part of the season, the measurements for determining general duty were made in this flume, which is about 10 miles below the intake (see fig. 2). This canal is new and in sandy or gravelly soil, which permits heavy seepage losses. The soil also is nearly all quite sandy, with gravel underlying. This accounts to a large extent for the low duty. The

area watered below this flume is approximately 4,280 acres, in alfalfa, young orchard, strawberries, and other small fruits.

The following table shows general duty on lands below flume No. 1:

Water used below flume No. 1, Kennewick canal, 1906.

Month.	Number of days.	Discharge.	Depth applied.
		Acre-feet.	*Feet.*
April	25	4,960	1.14
May	29	7,580	1.77
June	27	6,932	1.62
July	23	5,684	1.33
August	31	6,596	1.54
September	30	6,432	1.53
October	27	6,020	1.41
Total	192	44,204	10.34

Flume No. 3 is located about 1 mile west of the town of Kennewick. The bulk of the irrigated land is below this flume, and in order to determine the duty of water on this, with the seepage eliminated between flume No. 1 and flume No. 3, the records of the flow through flume No. 3 were obtained. The area irrigated below this is 3,900 acres, in alfalfa, young orchard, strawberries, and other small fruits, and gardens.

Water used below flume No. 3, Kennewick canal, 1906.

Month.	Number of days.	Discharge.	Depth applied.
		Acre-feet.	*Feet.*
April	25	4,168	1.07
May	29	6,516	1.67
June	27	6,072	1.55
July	23	4,500	1.16
August	31	5,068	1.29
September	30	5,126	1.31
October	27	5,194	1.33
Total	192	36,644	9.38

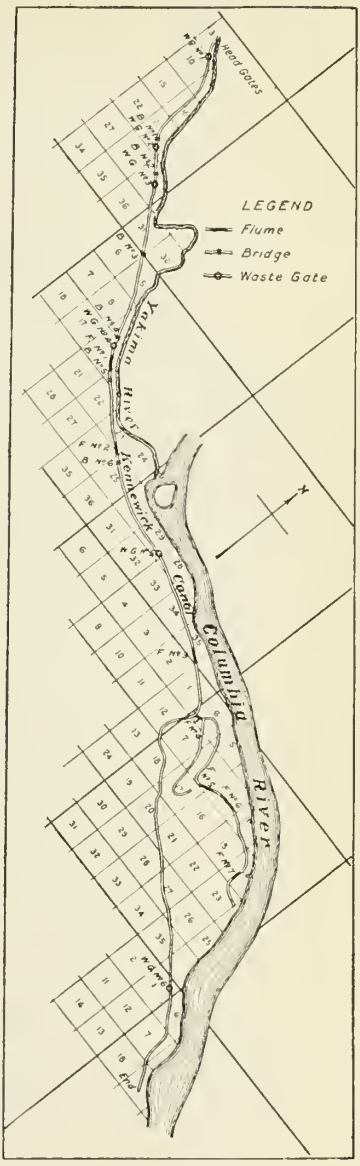

FIG. 2.—Sketch of Kennewick canal showing flumes, bridges, and waste gates.

The discharges through flume No. 4 for the season were also recorded in order to determine the duty on the two laterals below it. The area irrigated was 1,530 acres, principally in alfalfa, with some

young orchards. The following table shows the discharge and depths applied to the land:

Water used below flume No. 4, Kennewick canal, 1906.

Month.	Number of days.	Discharge.	Depth applied.	Month.	Number of days.	Discharge.	Depth applied.
		Acre-feet.	*Feet.*			*Acre-feet.*	*Feet.*
April	28	1,964	1.28	September	30	2,560	1.67
May	29	2,918	1.90	October	26	2,314	1.51
June	27	2,509	1.64	Total	193	16,725	10.91
July	22	1,871	1.22				
August	31	2,589	1.69				

DUTY OF WATER ON GARDEN TRACTS.

Immediately west of the town of Kennewick, in what is known as the "Kennewick Gardens," water received by 105 acres was measured by two Cipolletti weirs. These tracts are divided into 5-acre lots and are planted almost entirely to young orchards or strawberries, grapes, and other small fruits. The soil is for the most part sandy, with gravel underneath at a depth of from 18 inches to 3 feet. The whole area included in these gardens has a gentle and uniform slope toward the river, just sufficient to make it irrigate nicely. Figure 3, page 79, shows the subdivision of this tract and the way in which water is brought to each field.

Water used on "Kennewick Gardens" 1906.

Month.	Number of days.	Discharge.	Depth applied.	Month.	Number of days.	Discharge.	Depth applied.
		Acre-feet.	*Feet.*			*Acre-feet.*	*Feet.*
April	30	70.00	0.67	September	24	95.72	0.91
May	19	100.00	.95	October	27	87.92	.84
June	28	125.54	1.20	Total	169	662.94	6.31
July	21	96.04	.91				
August	20	87.72	.83				

From April 1 to May 10 the water used was estimated. Through August and part of September water was supplied to the garden tracts in two-day periods—on two days and off the next two. This method was used also in dividing the water between the main canal and the east branch at flume No. 4 during this period of shortage. It was turned down the main canal two days and through flume No. 4 the next two.

WATER REQUIRED IN SEEDING NEW LAND UNDER KENNEWICK CANAL.

In order to determine the quantity needed to start a crop of alfalfa on new land in the Kennewick district, measurements were made

of the water supplied to a tract in sec. 16, T. 8 N., R. 30 E. This field contains 40 acres. The land has a slight fall, being just sufficient

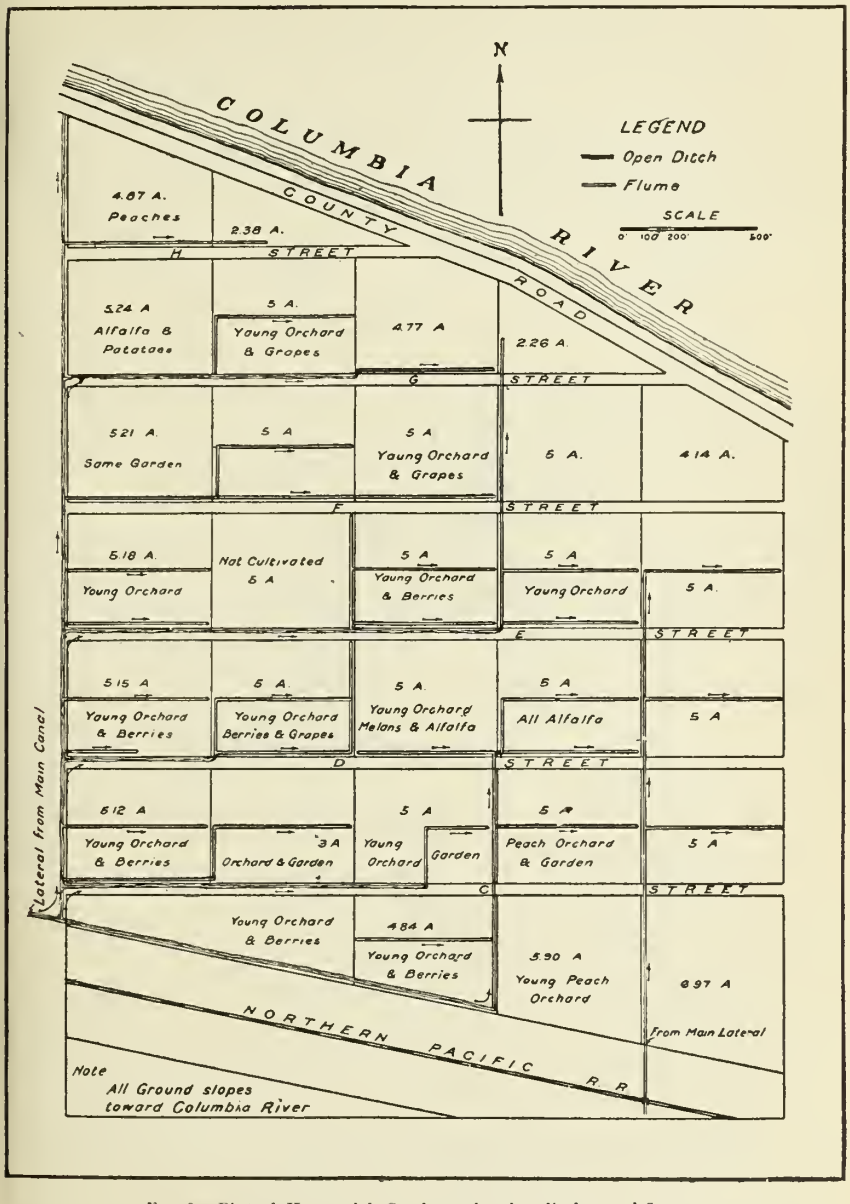

FIG. 3. Plat of Kennewick Gardens, showing ditches and flumes.

to irrigate easily without danger of washing. The soil is of the typical sandy nature with gravel underneath, at a depth of about 2½ feet.

Rye was sowed on the field early in February and started without being irrigated; then, about April 15, the first alfalfa seed was sowed on 5 acres which had been watered a few days before. Early in May about 2 acres more was sowed to alfalfa; this time on dry ground, and irrigated afterwards. By the end of the month this was farther advanced than that which was sowed in April. Seed was sowed a little at a time during the summer, as it is advisable to sow on only as much land as it will be possible to keep constantly moist while the grass is starting, for if the seed sprouts and water is then removed for a few days it is very apt to die. A total of 10.81 acres was seeded during the season.

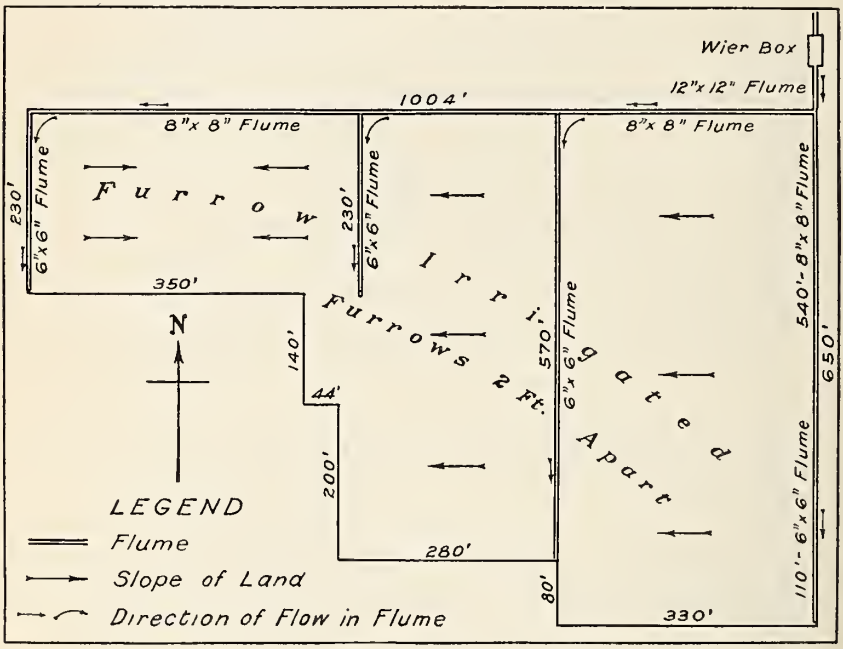

FIG. 4.—Plat of 10.81-acre irrigated tract at Kennewick, Wash., seeded in 1906.

The land was well leveled, furrowed at intervals of 2 feet, and irrigated entirely from flumes which were placed from 250 to 350 feet apart. (Fig. 4 and Pl. II, fig. 2.) It was found that 250 feet was far enough to run water in the furrows, and no doubt better results might have been obtained, in such sandy soil, if the furrows had been only a foot or 18 inches apart instead of 2 feet. The water was carried in flumes all the way from the main canal and was measured at the corner of the field over an 18-inch weir placed in a box 4 feet wide, 3 feet deep, and 13 feet long, through which the water passed with scarcely a perceptible velocity. This box was kept well cleaned of sand, and the readings of water passing over the weir were made morning, noon, and

night. The flow was very uniform, being usually an eighth to a quarter of an inch less at night than in the morning during the hottest weather, which showed the effect of evaporation from the main canal and 1,900 feet of flume through which the water passed in coming to the weir. The following table shows the water used and depths applied from April 16 to October 24:

Water used in seeding land under Kennewick canal, 1906.

Month.	Number of days.	Discharge.	Depth applied.	Month.	Number of days.	Discharge.	Depth applied.
		Acre-feet.	*Feet.*			*Acre-feet.*	*Feet.*
April	12½	15.84	1.47	September	20½	24.18	2.23
May	29	45.30	4.19	October	.....	30.38	2.81
June	27	39.14	3.62				
July	21½	17.68	1.63	Total	131	200.68	18.55
August	20½	28.16	2.60				

To be able to make some comparison between the amount of water needed for seeding new land and that required for fields with the crop established, some measurements were also made of water supplied to a few tracts which had been seeded a number of years. One field of alfalfa containing 4.62 acres received water as shown by table below. This tract is situated in the NE. ¼ NE. ¼ sec. 21, T. 8 N., R. 30 E. It was seeded about the last of August, 1904. The first three cuttings of the 1906 crop, measured in the stack by the "Government rule," made 40.9 tons, or 8.85 tons per acre. The soil is about the same as that of the newly seeded tract just discussed, but is on lower ground, and in October the crop showed the effects of subirrigation. When the arrangements for keeping the record of water on this tract were made in the spring there were no evidences that would lead one to suspect subbing later in the season.

Water used on N. C. Bowles's alfalfa field, 1906 (acres irrigated 4.62).

Dates of irrigation.	Number of days.	Discharge.	Depth applied.	Dates of irrigation.	Number of days.	Discharge.	Depth applied.
		Acre-feet.	*Feet.*			*Acre-feet.*	*Feet.*
April 18–21	4	[a] 5.00	1.08	August 15–17	3	3.77	0.82
May 9–12, 28–30	7	5.30	1.14	September 5–9	4	3.79	.82
June 16–21	6	5.40	1.17				
July 7–12, 26–29	10	8.85	1.91	Total	34	32.11	6.94

[a] Estimated.

GENERAL DUTY UNDER CANALS HEADING IN YAKIMA AND NATCHEZ RIVERS.

The table following shows the general duty of water under canals heading in the Yakima and Natchez rivers, in 1904.

General duty under canals heading in the Yakima and Natchez rivers, 1904.

	Acres irrigated.	Depth applied.					
		May.	June.	July.	Aug.	Sept.	Total.
CANALS HEADING IN THE YAKIMA RIVER.							
		Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
Selah & Moxee	5,500	9.00	9.25	9.75	9.75	9.00	46.75
Fowler	1,250	7.75	12.75	14.00	13.50	18.00	66.00
Hubbard:							
Moxee	3,000	3.12	7.12	10.75	8.75	7.00	36.74
New Reservation	1,400	7.50	19.25	37.25	26.50	39.75	130.25
Old Reservation	4,943	9.50	17.75	17.75	.....	.....	.....
Gilbert	2,500	17.00	15.75	15.13	11.00	.....	.....
Sunnyside canal	32,000	11.60	12.30	10.70	12.30	11.30	[a] 72.44
Prosser Falls Land and Irrigation Co	1,300	6.84	7.10	7.57	6.90	5.10	[b] 47.69
Northern Pacific Irrigation Co., Kennewick	3,500	19.00	18.75	17.75	18.25	.....	[c] 98.50
DITCHES HEADING IN THE NATCHEZ RIVER.							
Natchez and Cowiche	2,044	12.50	11.25	11.75	13.50	6.71	55.71
Union ditch	2,800	21.00	25.00	24.50	.....	.....	.....
New Shanno	900	16.50	14.75	17.00	18.25	.....	66.50
Yakima Valley Irrigation Co	3,600	8.75	10.00	9.20	10.50	12.55	51.00
Gleed	1,612	21.50	33.50	23.75	22.50	30.50	131.75
Wapatox	1,700	14.50	13.25	14.25	14.75	11.50	68.25
Selah Valley canal	5,500	4.60	9.00	7.50	10.00	9.00	40.10
R. S. and C	300	7.75	7.50	7.75	7.50	38.25	68.75

[a] April, 5.74; October, 8.5.
[b] April, 4.84; October, 7.16; November, 2.18.
[c] April, 7; September and October, 17.75.

In closing this discussion of the duty of water in the Yakima Valley, it should be repeated that the results of investigations along this line up to the present merely show the general irrigation practice, and indicate the quantities of water actually used under conditions as they now exist. These conditions in nearly every part of the valley could be largely improved, and the field is still open for investigations and studies that will show what is the best amount of water to use for the different crops and what are the best methods of application in order that the utmost benefit may be obtained from a limited supply.

SEEPAGE.

There is not a canal in the valley from which there is not more or less loss of water in transit. These losses are generally spoken of as caused by seepage and evaporation. However, it has been demonstrated in other places that the evaporation losses as compared to those caused by seepage are so light that they may be disregarded. This is doubtless true in the Yakima Valley. The loss by seepage from the Yakima canals is chiefly dependent on the character of soil through which they run. Where this is a finely divided sandy loam such as occurs in most parts of the valley the losses from this cause are believed to be generally light, but where the canals are built through soils which are very gravelly or perhaps nearly pure gravel the seepage losses are naturally very heavy unless very strenuous measures are adopted to prevent them. In other places much water is lost

along portions of the canals where the excavation has been through seamy basaltic rock or decomposed sandstone, such as occurs in parts of the valley. Usually losses from this cause are at the upper ends of the canals, but in the case of the Sunnyside canal the difficulty was encountered along the last 6 miles of its course.

Too steep grades sometimes are responsible for much seepage. This condition is found on some of the smaller early ditches built through gravelly soil. We have heard it argued that when the water is to be conducted through gravel or a porous formation it should go fast, but in canals built on this theory the velocities are such as to prevent silting of the channels and thus promote seepage.

Along the Sunnyside canal there is a condition not generally found in the valley, but which has been responsible for a large part of the seepage from this channel. In the construction of the canal many fills have been made across short gullies or depressions, where to follow the contour of the land would have necessitated wide detours; and frequently the upper banks have been either omitted or destroyed which allows the water to spread out over the land above the canal and form lakes. In cases where the fills are of considerable height quite large areas of land are sometimes flooded, and below such lakes are invariably found heavy seepage losses, large enough often to run in small streams away from the canal. To prevent these losses it has been the policy of the management in late years to build up and maintain the upper banks of the canal, so as to prevent the formation of the lakes.

On the canals where the difficulty is due to gravelly soil it has been the practice, to some extent, to excavate a foot or so below grade and then fill in with clay or fine material so as to form a puddle. Considerable of this work has been done on the Kennewick canal and also on the canal of the Benton Water Company. In the case of the Kennewick canal the clay was tamped in the bottom, and then the bottom and sides were plastered several inches thick with a mortar formed of the clay in a plastic state. This was then covered with a layer of gravel to prevent washing. The results of this work, so far as it went, were quite satisfactory, but it is difficult to find suitable clay for this purpose.

Some measurements have been made on several of the canals to learn the extent of seepage, but on most of the smaller canals it is almost impossible to get any reliable results on account of the numerous diversions which there is no satisfactory means of measuring; and if these are shut off along a stretch 2 or 3 miles long, the extra water will cause such a rise in the canal below as to be dangerous. For this reason most of the seepage tests have been made covering sections along which few diversions were made.

SEEPAGE LOSSES FROM KENNEWICK CANAL.

More measurements have been made on the Kennewick canal than on others, but conditions in this case are not at all typical as the seepage is perhaps many times greater than on any of the other important canals of the valley.

The following table shows the results of measurements and the sketch of the canal (fig. 2, p. 77) indicates when they were made.

Seepage losses from Kennewick canal.

Section of canal.	Miles.	Discharge at—		Loss.	Percent.	Date.
		Upper end.	Lower end.			
		Cub. ft. per sec.	*Cub. ft. per sec.*	*Cub. ft. per sec.*		
De Moss's bridge to flume No. 1	9.0	123.0	91.0	32.0	26.0	Sept. 9, 1904
Flume No. 1 to flume No. 3	8.6	91.0	68.0	23.0	25.2	May 11, 1906
De Moss's bridge to flume No. 1	9.0	161.0	131.0	30.0	18.6	Do.
Flume No. 1 to flume No. 2	2.6	131.0	126.0	5.0	3.8	Sept. 27, 1906
De Moss's bridge to flume No. 1	9.0	148.0	124.0	24.0	16.2	Do.
Flume No. 1 to flume No. 2	2.6	124.0	120.0	4.0	3.2	Do.
Flume No. 2 to flume No. 3	6.0	120.0	107.0	13.0	10.8	Oct. 16, 1906
De Moss's bridge to flume No. 1	9.0	78.6	68.8	9.8	12.4	Do.
Flume No. 1 to flume No. 3	8.6	68.8	57.9	10.9	15.8	Sept. 9, 1904

The above lengths of sections take into consideration the portions of canal in earth and do not include flumes from which there was practically no loss. The results show quite a decided improvement in the channel in two years, due to the deposit of silt and the puddling work which has been done.

In 1904 the total loss from the De Moss's bridge to Kennewick was 45 per cent, while in 1906, on September 27, it was only 27.7 per cent, but there was 20 per cent more water in the canal than was flowing on the former date. The total seepage loss from the entire length of this canal is probably more than 50 per cent at present.

SEEPAGE LOSSES FROM SELAH-MOXEE CANAL.

The following table shows the results of measurements made in the Selah-Moxee canal in 1906:

Seepage losses from Selah-Moxee canal, 1906.

Section of canal.	Miles.	Discharge at—		Loss.	Percent.	Date.
		Upper end.	Lower end.			
		Cub. ft. per sec.	*Cub. ft. per sec.*	*Cub. ft. per sec.*		
Flume to Butterfield's bridge	1.42	53.3	51.5	1.8	3.4	July 3
Do	1.42	49.8	48.6	1.2	2.4	Aug. 21
Flume to northeast corner section 21	2.60	49.8	47.7	2.1	4.2	Do.
Cemetery to Rankin hopyard	1.57	29.0	28.8	.2	.7	July 6

The excavation from the flume at the entrance of the Moxee district to the northeast corner of section 21 is largely through seamy

basaltic rock, and the seepage is greater than on most parts of the canal farther down. Measurements were attempted on other sections, but on account of the difficulty in closing off the service gates of farms the results were not considered reliable.

SEEPAGE LOSSES FROM THE SUNNYSIDE CANAL.

In 1904 a number of measurements were made at various points along this canal by hydrographers of the United States Geological Survey, and the seepage losses and waste were found to be very small. The seepage from the intake to Zillah, a distance of 17 miles, was 4.5 per cent. The excavation in this distance is all through the sandy loam or volcanic ash soil.

Measurements made on laterals of this system at various places also show very slight seepage losses, even where laterals are run through the Sunnyside sand, the light loss being due to the flat grades which allow the silt to be deposited.

RELATION BETWEEN IRRIGATION AND DRAINAGE.

The experience in the Yakima Valley has been such as to confirm the rule that may be laid down with reference to practically every irrigated district in the West, or wherever irrigation is practiced, that drainage is always a necessary adjunct and must go hand in hand with it. Some sections are so far favored by nature as to have this requirement supplied, but the majority of the irrigated districts of the West are not so fortunate in this respect and the Yakima Valley is one of these. Where natural drainage is not afforded it must sooner or later be supplied by man. The amount of water which is actually taken up by plants is perhaps but a small part of what is usually applied to the land in irrigation. The excess water with the exception of what is evaporated soaks away into the soil and seeks the lower levels; and it is from the accumulation of this water in the low places that the necessity of drainage comes.

Before irrigation was begun the subsoil on the higher lands was practically without moisture and its capacity for absorption was therefore large, so that the excess water for a few years was taken care of, and the necessity for drainage in many places was not appreciated until much damage had resulted. There are thousands of acres of what has been valuable and productive land, now practically worthless swamp or alkali waste because the need of drainage was not soon enough realized and the means for it provided. Six drainage districts have been organized in Yakima County and thousands of dollars have been spent for the construction of ditches where fifteen years ago the idea of drainage was not dreamed of and where if one had suggested such a future need he would have been considered mentally unbalanced.

This work was delayed too long, and the delay has so increased the cost of construction that where thousands have now been spent, hundreds would have been more than ample if it had been undertaken before the damage had gone so far. These lands requiring drainage are not confined to the Yakima country, but are found throughout the valley wherever irrigation has been practiced for any length of time.

The lowlands, especially those under the lower or older canals, are the first to suffer, and it is not many years from the time high line ditches are built and in operation until the injury begins. The injury, however, is not always to the low-lying lands alone; in some places the need of drainage is plainly evident even on hillsides with comparatively steep slopes. This is due to the outcropping of hardpan or impervious strata along which the water gradually works from the higher levels, and coming out on the hillsides and evaporating leaves the fatal alkali, which destroys the crops and ruins the land.

The effect of irrigation upon ground water conditions are best observed by noting the rise or fluctuations in wells, and the rapidity with which conditions change in places is remarkable. The following table with reference to wells in the Sunnyside district will illustrate the point, but this is not the only place where such a state exists.

Water level in wells near Sunnyside in 1902.

Well.	Date of digging.	Depth to water when dug.	Depth to water now.	Well.	Date of digging.	Depth to water when dug.	Depth to water now.
		Feet.	*Feet.*			*Feet.*	*Feet.*
No. 1	1890	80	5.0	No. 6	1893	53	0.0
No. 2	1900	90	20.0	No. 7	1900	15	1.0
No. 3	1899	42	.0	No. 8	1899	40	6.0
No. 4	1892	54	4.0	No. 9	1898	53	15.0
No. 5	1894	50	3.5				

In the Yakima district a large amount of drainage should be done, and also in the Ellensburg district there are considerable areas now worthless for anything more than pasture, all due to the same cause—irrigation. At Kennewick, where the summer of 1906 was the fourth season that water had been flowing in the canal, there is increasing evidence of the need of drainage, and already several hundred acres have been transformed from sandy desert to duck ponds.

The question of drainage is one of growing importance with every year that irrigation continues, and now that irrigation is being widely extended to the higher levels it certainly behooves those who are interested in or have highly improved lands and comfortable homes below such projects to be endlessly vigilant lest that which has destroyed other homes creep upon them unawares and take theirs also. Experience has shown that delays are fatal when the struggle

is against the combination of water and alkali, and for this reason all possible precautions should be taken in the future to forestall such injuries as have already come upon so many sections of the valley, due to neglect in providing drainage in proper time.

GOVERNMENT IRRIGATION WORK.

In the entire Yakima project, which is being handled by the Reclamation Service, there is approximately 350,000 acres of land, most of which lies above the lines of existing canals. This land is not found in one solid body, but is scattered more or less throughout the different parts of the valley, and for this reason the reclamation can not well be done all at one time, and the project is divided into subprojects or units which will be developed separately. (See map, Pl. I, p. 12.)

TIETON UNIT.

Under the Tieton unit, now in course of construction, will be reclaimed about 24,000 acres of land lying west of North Yakima, in a district especially well adapted to fruit growing. One million two hundred and fifty thousand dollars has been set aside for this work, which consists of the construction of 12 miles of main canal in the Tieton Canyon, with diverting dams, head works, tunnels and other appurtenant structures. There will be 13,000 linear feet of tunnel, 44,000 linear feet of concrete lining in the canal, 4,000 linear feet of unlined earth canal, and 1,000 feet of concrete flumes. Contracts for a part of the concrete work were let November 15, 1906, but most of the construction will be done by the Government, by force account. The laterals and distribution system will be constructed also during the season of 1907 and it is hoped to have water upon the land in 1908.

The land under this subproject will probably be divided into 40-acre tracts with the exception that present owners may be allowed to hold a limit of 80 acres; all in excess of this is to be deeded in trust to the Water Users' Association, to be disposed of.

SUNNYSIDE UNIT.

The Sunnyside subproject consists in the improvement and extension of the Sunnyside canal, which has been purchased by the Government, to irrigate about 40,000 acres in addition to what is already under cultivation. This will necessitate the replacement of present structures, enlargement of the canal, and construction of inverted siphons through which the water will be carried to lands near Mabton and Prosser.

The development of power in a few places is also contemplated, which will be used for pumping to high lands above gravity flow. One million one hundred thousand dollars was allotted for this work

out of which amount $250,000 was paid for the present canal. Eight thousand dollars more will be needed to completely carry out the work as planned.

RESERVATION UNIT.

Under the reservation subproject is contemplated the irrigation of about 100,000 acres of land upon the Yakima Indian Reservation. This land, as was elsewhere explained, is now held in 80-acre allotments by the Indians. Recent legislation has provided a way by which each owner may dispose of 75 per cent of his holdings in order to be able to improve the rest.

This makes it possible for whites to secure title to land in this district. No allotment has been definitely made for doing this work, but $1,000,000 will probably be devoted to it.

UNITS IN KITTITAS AND BENTON COUNTIES.

In Kittitas County there is a large body of land east of Ellensburg, above present canals, which will probably be irrigated sooner or later, as funds and water become available. This tract embraces about 65,000 acres.

In Benton County about 165,000 acres could be reclaimed, the larger part of which lies on the north side of the Yakima River, extending around to the north of the Rattlesnake Mountains to Priest Rapid, on the Columbia River. On the south side of the river, lying above the present Kennewick canal, there is also a considerable area of good land that could be reached by carrying the water across in pipes.

The work of the Reclamation Service also includes the construction of dams at the various reservoir sites at the headwaters of the streams. There are five of these sites, with an aggregate storage capacity of 370,000 acre-feet. Temporary dams are now in course of construction at Bumping Lake and at Lake Clealum.

As for the opportunities for securing lands in the Yakima Valley, it should be explained that there are practically no cheap lands remaining; that is, lands which would appear cheap in comparison with lands in most other localities. Raw lands such as were sold fifteen years ago with water rights for $35 to $50 per acre now bring from $150 to $200 per acre, and the price is not considered high where the same lands with bearing orchards are valued at from $500 to $1,000 or more per acre. There is a considerable area of such land now under ditch, and when the Tieton canal is completed by the Government there will be added about 24,000 acres, practically all of which will be valuable fruit land. Lands which will be under this canal are now selling for $50 to $200 per acre without water rights, while the cost of water is estimated at about $55 per acre, on ten years' time,

without interest. Purchasers of land under the Tieton canal are restricted to 40 acres each, and are required to reside within 20 miles of their holdings. In some localities, where conditions are not so favorable for fruit growing, unimproved lands with water rights may be purchased at prices varying from $60 to $100 per acre.

In addition to the opportunities for buying raw land, the improvement of transportation facilities is causing many of the large farms to be divided into small tracts, thus inducing a more intensive farming and affording homes for many more families. Ten acres will probably be about the average size of farms in most parts of the valley, and this area of land in bearing orchards, small fruits, or garden truck will afford a larger revenue than the ordinary quarter section in most farming districts.

The further extension of Government reclamation work as contemplated will make thousands of acres more land available for settlers, and it is estimated that when all this land is under cultivation it will provide homes for at least three times the valley's present population, and this estimate we believe to be conservative

Very often in a new country settlers with limited means find it convenient to secure employment for themselves and their teams away from their farms during a part of the year. In so doing they add considerably to their incomes while their orchards are young, or before the returns from the land are sufficient to maintain their families, and in this way they are enabled to acquire homes where, without the opportunity for outside employment, it would be impossible to do so. The unprecedented demand for men and teams on railroad construction, irrigation canals, and other development work affords better opportunities now than ever before for getting a home in the Yakima Valley.

ACKNOWLEDGMENTS.

In closing this report we wish to acknowledge the assistance rendered by officers of the various canal companies and other interested parties throughout the Yakima Valley, who, by their kindly cooperation, have so materially aided in conducting the investigations which have been carried on during the last few years. As a large per cent of the statistical matter herein compiled was gathered by or under the direction of Prof. O. L. Waller, we take pleasure in extending to him the credit, and also wish to express appreciation for this assistance.

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